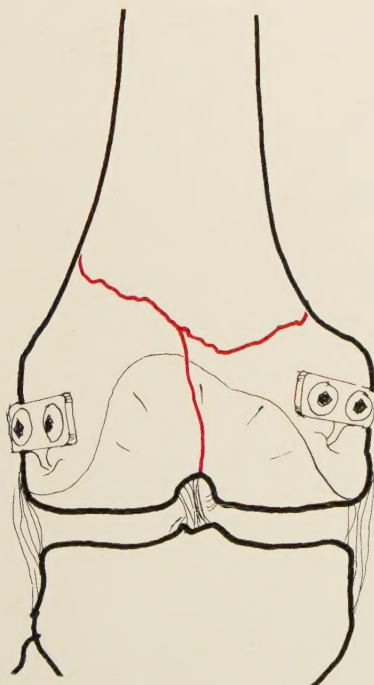


Distal Femoral Fractures

and a new

Fixation Device

Lars Kolmert



Lund 1982.



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Distal Femoral Fractures and a new **Fixation Device**

Lars Kolmert

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Printed in Sweden
Studentlitteratur

Lund 1982

To my family

"En åldrig tjänstepiga, mot 40 år gammal, hade fallit från en stega av 4 alnars höjd, mot stengatan och afbrutit dess vänstra lår.

Vänstra lårbenspipan var afbruten en tvärhand över condylos och spetsiga ändan av nedre stycket spände mot huden baktill mellan tibias böjmuskler. Den öfre spetsen hade genombrutit huden på inre sidan af låret.

Efter några dagar stack öfre benändan sig till två tvärfinger genom huden och benspetsen avsågades. Föga lindring vanns dymedelst. Inom tre dagar viste sig svarta gangränade fläckar. När desse öppnades utflöt en mängd var och stycken av fetthinnan.

Efter trenne veckors mödofulla förlopp tillkom ett förtärande durklopp, liten yrsel och döden. Nedre ändan av lårbenspipan fants rämnad och aldeles skild i två delar emellan condylos. Jag tvivlar om de någonsin stå at hielpa på annat sätt än med amputation".

Ur Olof Acrel

"Chirurgiska Händelser", Stockholm 1759.

This detailed description of an open displaced bicondylar femoral fracture, leading to infection, gangrene and death, was made by the pioneer of swedish surgery, Professor Olof Acrel, M.D. at Kongl Serafimer Lazarettet, Stockholm in 1755.

CONTENTS

	Page
INVESTIGATIONS IN THESE THESIS	7
DEFINITIONS	8
INTRODUCTION	9
PURPOSE OF THE INVESTIGATIONS	13
SERIES OF FRACTURES/OSTEOTOMIES STUDIED Table 1	14
SUMMARIES OF PAPERS	
Paper I	15
Paper II	16
Paper III	18
Paper IV	20
Paper V	22
SURVEY OF PAPERS ON DISTAL FEMORAL FRACTURES Table 2	23
GENERAL DISCUSSION	24
GENERAL SUMMARY	30
SUMMARIZED PRINCIPLES OF TREATMENT	31
CONCLUSIONS	32
ACKNOWLEDGEMENTS	33
REFERENCES	34
PAPERS	
I Epidemiology and treatment of distal femoral fractures in adults	37
II Deformities, gonarthrosis and function after distal femoral fractures	53
III An experimental study of devices for internal fixation of distal femoral fractures	75
IV Internal fixation of supracondylar and bicondylar femoral fractures with a new semi-elastic device	95
V Supracondylar femoral fractures as a complication to Ender nailing of trochanteric fractures	127

TABLES	Page
1 Series of patients/specimen studied	14
2 Survey of papers on DFF	23

FIGURES

1 Age and sex distribution of distal femoral fractures	15
2 Classification of distal femoral fractures	17
3 Biomechanical test of Rush pin in supracondylar osteotomy	19
4 Operative technique for semi-elastic fixation	21
5 Bicondylar fracture 9 months after semi-elastic fixation	

This thesis is based on the following papers:

- I Kolmert, L. and Wulff, K.

Epidemiology and treatment of distal femoral fractures in adults. Accepted for publication in Acta Orthopaedica Scandinavica.

- II Egund, N. and Kolmert, L.

Deformities, gonarthrosis and function after distal femoral fractures. Accepted for publication in Acta Orthopaedica Scandinavica.

- III Kolmert, L., Persson, B.M. and Romanus, B.

An experimental study of devices for internal fixation of distal femoral fractures. Accepted for publication in Clinical Orthopaedics and Related Research.

- IV Kolmert, L., Egund, N. and Persson, B.M.

Internal fixation of supracondylar and bicondylar femoral fractures with a new semi-elastic device. Accepted for publication in Clinical Orthopaedics and Related Research.

- V Kolmert, L. and Persson, B.M.

Supracondylar femoral fractures as a complication to Ender-nailing of trochanteric fractures. Archives of Orthopaedic and Traumatic Surgery 97: 51-55, 1980.

DEFINITIONS

The distal femoral fracture (DFF) involves the distal 15 cm of the femur; it comprises the following major fracture types

The supracondylar femoral fracture usually does not involve the articular cartilage. In a few of these fractures the proximal fragment might penetrate the suprapatellar pouch and interfere with the patellar articulation

The unicondylar femoral fracture is intra-articular and separates one of the condyles from the femur

The bicondylar femoral fracture is intra-articular and separates both the condyles from the femur

The transcondylar femoral fracture extends through the weight-bearing part of the articular cartilage

INTRODUCTION

Olof Acrel (1759), the pioneer of swedish surgery, chief surgeon at the Serafimer Hospital in Stockholm from the start in 1752 through 1806, described two cases of distal femoral fractures (DFF). One was caused by a fall from a ladder, it was open and led to death from infection (page 4). The other was caused by a falling barrel of wine, it was closed, oblique and displaced, and the patient, a young man, was kept in bed for 6 months when the fracture had healed with 7 cm shortening.

Astley Cooper in 1824 stated that the oblique fracture of the condyles of the femur "is liable to terminate most unfortunately by producing deformity and by preventing flexion of the knee joint." He considered the fractures of the condyles to be infrequent, but described carefully the treatment of two open displaced fractures. One, in a young male, resulted in uneventful healing and "free use of the joint" and the other, a bicondylar closed fracture in a man aged 76, finished with sepsis and death after three weeks. Treatment was bed-rest and splints in both.

The experiences of Acrel and Cooper with deep infection, death, prolonged bed confinement, malunion and shortening have been shared by generations of surgeons faced with the distal femoral fractures. The difference in treatment and outcome between these fractures and those of the proximal two thirds of the femur has widened over the last decades. Established methods of treatment of fractures in the proximal two thirds of femur usually permit immediate ambulation and restoration of pre-fracture function. By comparison, the treatment of fractures of the distal third of the femur rests on small series of published material, diverse methods and a high risk of early complications.

The continuous traction by adhesive plaster of femoral fractures was improved upon by Steinmann in 1907 and Kirchner in 1909 who

introduced skeletal traction thus avoiding attachment to the skin. Tibial traction was shown by Mahorner and Bradburn (1933) to give discouraging results in most cases of DFF. Modlin (1945) improved the traction by supplementing skeletal vertical traction of the distal femoral fragment, thus counteracting the pull of the gastrocnemius muscles.

Even though traction is still the common initial treatment, closed methods have fallen into disrepute because alignment is often unsatisfactory and as with hip fractures the majority of the patients are too old to endure confinement in bed.

There are two principles of internal fixation, either inserting nails into or screwing plates on to the bone. The intramedullary nailing for femoral fractures started with Rush (1939). For the DFF the commonly recognized migration of the pins, especially in osteoporotic bone initiated a modification with a loop at the distal end of the pins (Rush 1968). No material has, however, been presented using that device as yet. The plates have been either straight as designed by Judet (Judet 1970, Vidal et al 1976), Neer (Shelton et al 1977) and the AO-group (Trentz et al 1977), or angled with the blade introduced through the condyles as designed by Blount (Umansky 1948) and the AO-group (Müller et al 1970, Chiron et al 1973). The AO angle condylar plate was introduced during the sixties and has been one of the most commonly used. The principles of anatomical reduction and rigid fixation (Danis 1949) which permit early motion of the knee, were early adopted by the AO-group. However, Olerud (1972), Schatzker et al (1974, 1979) found the condylar plate unsuitable for osteoporotic bone. Schatzker et al (1974) and Benum (1977) therefore further stabilized this system with the use of acrylic cement.

A new solution to the problem of migration of the intramedullary pins was introduced by using two intramedullary rods combined with transcondylar screws at the distal end (Zickel et al 1977). Using

this method in two cases in 1978 we experienced disadvantages during insertion of the rather stiff and blade-shaped rods which forced into rotation and displaced the fracture. Earlier, three patients, unsuccessfully treated by other methods, had prompted us to evolve a better solution to the problem of internal fixation for these patients with bone fragility thereby avoiding prolonged skeletal traction. Successful management programs with internal fixation and early mobilization for patients with femoral neck fractures illustrate the value of such an approach. Similarly patients with tibial shaft fractures are now being successfully mobilized following non-rigid internal fixation and a supporting cast-brace (Önnerfält 1977). These examples stimulated us to find a solution between the extreme alternatives of either rigid fixation or traction in bed, which until now had been the principal choices in the management of DFF.

PURPOSE OF THE INVESTIGATIONS

1. To analyze age, sex, previous and current diseases and fractures of consecutively treated distal femoral fractures from Lund and Malmö and to study types of trauma, types of fractures and types of treatment (Paper I)
2. To re-examine available patients from that group, classify the fractures, identify deformities and occurrence of arthritis and to evaluate late function (Paper II)
3. To investigate biomechanical characteristics of two of the most commonly used internal fixation devices as well as two new devices (Paper III)
4. To stabilize displaced supracondylar and bicondylar femoral fractures prospectively with a newly developed, semi-elastic fixation device, and assess the primary results of the method (Paper IV)
5. To describe the types of supracondylar femoral fractures which might appear during or after Ender-nailing of trochanteric fractures and to propose a method of treatment which avoids traction in bed (Paper V)

Table 1. Series of fractures/osteotomies studied in paper I - V

Paper	N	Period	Mean age or range	Proportion female	Type of supra-	Type of condylar fracture	Type of examination
I	137	1969-76	65	0.7	39	33	Retrospective
II	62*	1969-76	65	0.7	12	15	"
III	34**	-	60-96	0.5	34	-	Biomechanical
IV	34	1978-80	65	0.8	24	-	Prospective
V	7***	1977-79	66-96	6/7	7	-	Selective

* These patients are re-examined from Series I

** Post-mortem specimen with supracondylar osteotomies

*** Two operated patients are included in Series IV

SUMMARY OF EACH PAPER

I EPIDEMIOLOGY AND TREATMENT OF DISTAL FEMORAL FRACTURES IN ADULTS

Four per cent of all femoral fractures are situated in the distal third, 10 per cent in the midshaft and 86 per cent in the proximal third. The annual incidence of distal femoral fractures (DFF) was calculated from the Malmö figures to be 51 per million inhabitants over 16 years.

N:o of
fractures

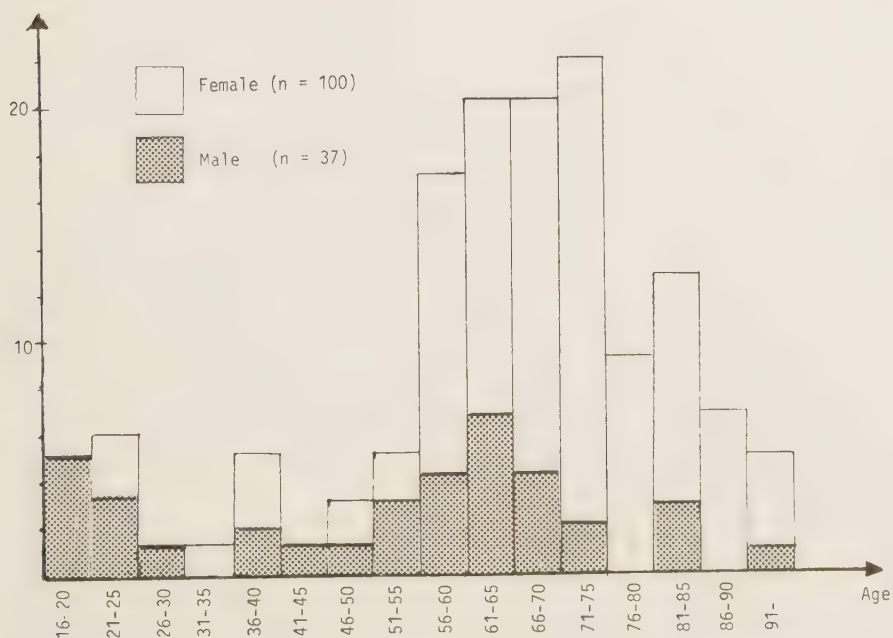


Fig 1. Age and sex distribution of distal femoral fractures.
Mean age 65 years. Median age 68 years

From 1969 through 1976, 137 fractures were collected from the Departments of Orthopaedic Surgery in Lund and Malmö (Fig 1). Eighty-four per cent of these were seen in patients over 50 years

of age. There was a small peak dominated by males in the youngest age group and a big peak in the elderly with female dominance. Nineteen per cent had other general factors predisposing to fracture and 42 per cent had previous or current diseases of the fractured leg. Seventy-three per cent were women and 61 per cent were caused by moderate trauma. The fractures were classified into supracondylar, unicondylar and bicondylar. The age pattern was similar for the three groups, but the mean age for the supracondylar group was 69, for the bicondylar group 61 and for the unicondylar group 65. Ten fractures were open.

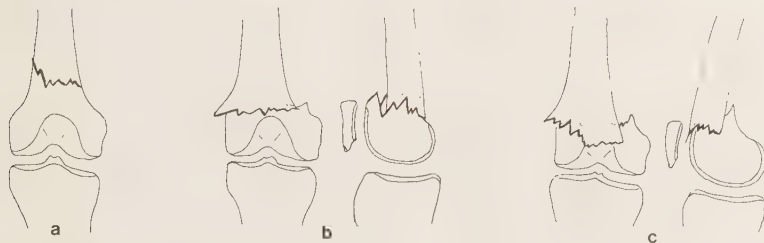
The results of treatment were considered acceptable in about 2/3 of all fractures after both surgical and nonsurgical treatment. The treatment for unicondylar fractures was considered satisfactory in 28/32, and the treatment for supracondylar and bicondylar femoral fractures in 58/88. The nonsurgical treatment in traction showed a mean of seven weeks for 47 patients, all with supracondylar and bicondylar fractures. The surgical results for bicondylar and supracondylar fractures were unsatisfactory in 4/17 operated with condylar plates, 4/5 with Rush pins and 4/8 with screws and for unicondylar fractures in 1/6 stabilized by screws. All unsatisfactory, except one, were over 50 years of age. The disadvantages of the nonsurgical treatment for supracondylar and bicondylar fractures was the long time in traction and of the surgical, the failures of fixation in fragile bone.

II DEFORMITIES, GONARTHROSIS AND FUNCTION AFTER DISTAL FEMORAL FRACTURES

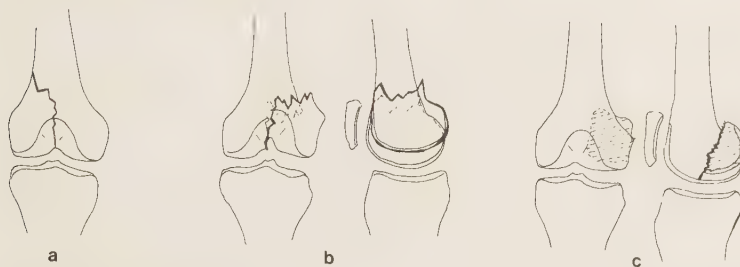
Sixty-two distal femoral fractures from the material described in paper I were re-examined after a mean of 5 years. The goal was to study deformities in the healed fractures, the presence of arthritis and the final function. The basis for this was the classification into supracondylar (extra-articular), unicondylar and bicondylar fractures with subdivisions according to the displacement in

the supracondylar fracture (or supracondylar part of the bicondylar fracture), intercondylar and transcondylar fractures (Fig 2).

Supra-condylar femoral fractures



Uni-condylar femoral fractures



Bi-condylar femoral fractures

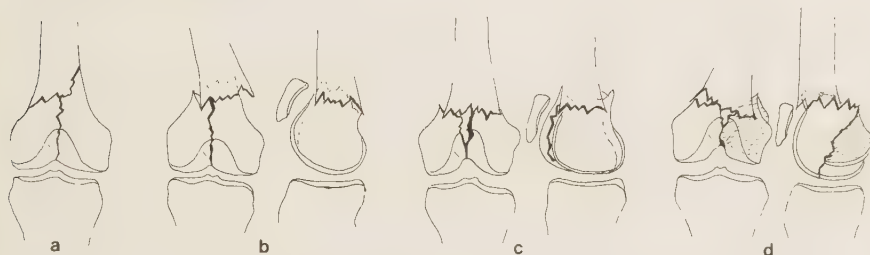


Fig 2. Type and displacement of distal femoral fractures.

Supracondylar fractures

a) no displacement b) supracondylar displacement c) supracondylar displacement and comminution

Unicondylar fractures

a) no displacement b) unicondylar displacement c) transcondylar displacement

Bicondylar fractures

a) no displacement b) supracondylar displacement c) supracondylar and intercondylar displacement d) supracondylar, intercondylar and transcondylar displacement

Radiographic criteria for classification was obtained by adding the axial projection of the patellar joint to the common standard projections in the frontal and the lateral planes. The most common deformity after bicondylar fracture, was varus and anterior angulation, after supracondylar, varus angulation, after medial unicondylar, varus, and after lateral unicondylar, valgus angulation.

Arthrosis in the femoro-tibial articulation was found in 3/51 and in the patellar articulation in 14/51, when excluding those with ipsilateral arthrosis at fracture and those with contralateral arthrosis at follow up. All three with femoro-tibial and seven of those with only patellar arthrosis complained of discomfort in the knee and four did not. The highest frequency of arthrosis was found in the bicondylar fractures with intercondylar and transcondylar displacement. For the latter groups severe trauma as a rule preceded the fractures. Only those with concomitant transcondylar fractures showed significant decrease in function, assessed according to Ranawat et al (1976). The intercondylar diastasis and incongruence of joint surfaces, expressed as difference in joint level, were found to cause arthrosis when exceeding 3 mm. Thus exact reduction and firm stabilization of the condylar part of such distal femoral fractures seemed essential. The findings supported the anatomical classification in being of prognostic value for the treatment and the results.

III AN EXPERIMENTAL STUDY OF DEVICES FOR INTERNAL FIXATION OF DISTAL FEMORAL FRACTURES

Reported failures after surgery of distal femoral fractures and our own series and experiences initiated the development of a new, semi-elastic internal fixation (ECS). It consisted of two Ender-nails, where one is inserted from each condyle and connected to two cancellous screws by a special coupling piece. In this study four intramedullary devices (ECS, Rush, Zickel and Ender) and one onlay (AO-condylar blade plate) were tested on supracondylar cadaver os-

teotomies, in 15 paired preparations. They were submitted to constant bending rate in abduction and extension.

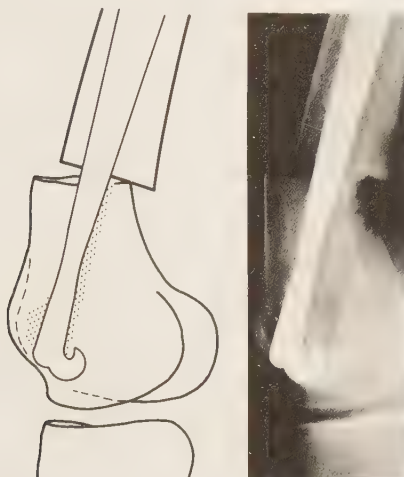


Fig 3. The cutting through cancellous bone of a Rush pin in biomechanical test

The condylar plate was the strongest and showed the lowest flexibility. The two Ender nails and the two Rush pins cut through the condyles when loaded, losing their stabilization (Fig 3). The Zickel nails were more sufficient, but displaced the distal fragment anteriorly and resulted in fractures proximally. The semi-elastic device combined easy insertion, with rigid fixation in the condyles. The elasticity of the intramedullary component in combination with a distal anchorage prevent cutting through the condyles. The angle plate was the most rigid and produced fractures through the proximal screw holes in all specimens when loaded in extension. In abduction it bent keeping the bony ends apart. This contrasts to the intramedullary elastic devices which retain their position after loading with contact between the fragments.

A calculation for need of external support was made comparing the moment for an estimated deflexion of 10° at the osteotomy site with the test results. The Rush and Ender nails seemed insufficient with-

out external support, while the condylar plate, the Zickel and the semi-elastic devices seemed sufficient without this.

IV INTERNAL FIXATION OF SUPRACONDYLAR AND BICONDYLAR FEMORAL FRACTURES WITH A NEW SEMI-ELASTIC DEVICE

This prospective series comprised 54 distal femoral fractures collected from seven hospitals. The aim was early mobilization. Surgery was advocated in 34 displaced fractures. Fifteen undisplaced fractures were treated in plaster or cast-brace and six fractures were treated in traction: one young male with bilateral gun-shot fractures, four aged patients because of poor general condition, of which one was transferred to surgery after six weeks because of bedsores, and one expired one day after admission.

The mean age at surgery was 65 years. Four patients died before union had occurred and one refused re-examination. Thus 20 supracondylar and nine bicondylar fractures remained for the follow-up. Twenty-one patients suffered from disease or had previous fractures mostly involving the hip.

Semi-elastic fixation consists of one intramedullary nail applied from each condyle and connected to two cancellous screws by a coupling-piece ensuring distal stabilization (Fig 4). Short nails were used in those previously operated with a nail and plate or endoprotheses in the hip. Following surgery an anterior plaster slab was applied for two weeks and then a hinged cast-brace depending on the type of fracture.

No infection appeared. One nonunion developed in an open comminuted bicondylar fracture with concomitant patellar fracture. At follow-up the range of motion in the knees was close to 90° or more for 8/9 bicondylar fractures and 14/18 supracondylar and mobile patients. The angular varus - valgus deviation was less than 8° for 27 patients. The shortening showed a mean of 1.4 cm and was less than 2.5 cm for 23 patients. Patellar pain on palpation was present in

one bicondylar fracture. The results were excellent in 12, good in 9, fair in 5 and poor in 3 patients. The classification of fractures (Paper II) was sufficient for this series. The semi-elastic fixation adapted well to osteoporotic bone and prevented failures otherwise seen with rigid internal fixation (Fig 5).

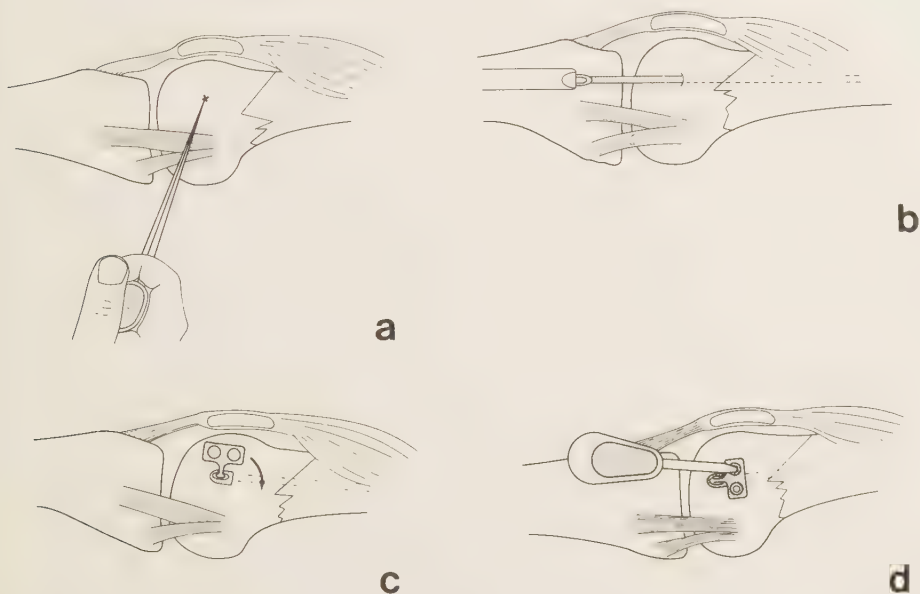


Fig 4. Technique for insertion of semi-elastic fixation. a) site for insertion of nail b) introduction of the first nail c) application and locking of the coupling piece d) application of the screws

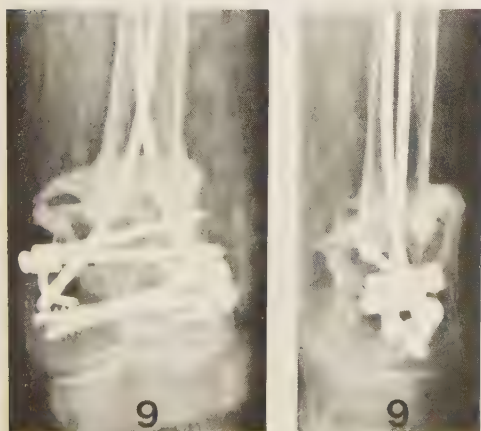


Fig 5. A female, aged 73 and osteoporotic. Bicondylar and comminuted fracture after 9 months. Antero-posterior and lateral view

V SUPRACONDYLAR FEMORAL FRACTURES AS A COMPLICATION TO ENDER-NAILING OF TROCHANTERIC FRACTURES

Seven patients had supracondylar femoral fractures at the site of insertion of Ender nails for trochanteric fractures. The most common fracture type extended obliquely from the insertion medially, in proximo - lateral direction. In three patients prolonged traction resulted in malposition. Additional nailing was successful in one patient and resulted in prolonged healing in another. Two underwent semi-elastic fixation of the supracondylar fracture; the first after removal of the Ender-nails and application of a nail and plate for the trochanteric fracture, the second, while retaining two of the Ender-nails for the trochanteric fracture. Although 96 and 92 years of age both were sufficiently stabilized and mobilized out of bed immediately following surgery. The first patient expired from a gastric ulcer before union and the last patient went home with both fractures united three months later.

The insertion site in Ender-nailing for trochanteric femoral fractures should be gently prepared using an awl and the nail introduced avoiding penetration of the opposite cortex. Semi-elastic fixation is recommended in the event of sustaining a supracondylar fracture.

Table 2. Survey of papers on distal femoral fractures 1966-82

Year	Author	N	Proport No of		Mean age	Proport female	Treatment		Delayed union		Infection		Re-mark	Max dist above knee (cm)
			severe trauma	re-exam cases			S	NS	S	NS	S	NS		
1966	Stewart et al	422	0.6	213	40	0.5	71	142	Diverse	20	14	4	?	R D 1/3
1967	Neer et al	110	?	77	55	0.4	36	41	Diverse	9	2	8	2	R 7.5
1970	Mooney et al	200	?	200	42	0.4	-	200	Cast	-	6	-	0	P D 2/3
1971	Slätis et al	21	0.8	16	37	0.4	21	-	AO	0	-	1	-	S D 1/3
1972	Olerud	16	1.0	15	43	0.4	16	-	AO	2	-	3	-	S 7.5
1977	Benum	14	?	14	75	1.0	14	-	AO+cam	1	-	0	-	R Sc*
1977	Zickel et al	14	0.3	11	64	0.7	14	-	Zickel	0	-	0	-	P? D 1/2?
1977	Trentz et al	199	0.8	164	?	0.4	199	-	AO	21	-	7	-	R D 1/2?
1979	Schatzker and Lambert	83	0.8	35	61	0.4	35	-	AO	8	-	2	-	R 20?
1980	Seinsheimer	84	?	47	53	0.5	23	24	Diverse	4	4	?	?	R 9
1982	Kolmert and Wulff	137	0.4	120	65	0.7	45	92	Diverse	3	2	3	1	R D 1/3
1982	Kolmert et al	54	0.5	29	66	0.8	34	21	Semi-el	1	-	0	-	P D 1/3

S = Surgical

NS = Non-surgical

P = Prospective

R = Retrospective

S = Selective

D = Distal

Sc*= Supracondylar (extra-articular)

GENERAL DISCUSSION

The terms "distal femoral fracture" (DFF) or "supracondylar" fractures (Table 2) are taken by some authors to include only the distal 7.5 or 9 cm of femur (Neer et al 1967, Seinsheimer 1980), the distal third (Stewart et al 1966) or even the distal half (Schatzker et al 1974, Trentz et al 1977 and Zickel et al 1977).

The term "supracondylar" includes intra-articular fractures in some papers (Neer et al 1977, Schatzker et al 1974) while others exclude these fractures (Benum 1977, Seinsheimer 1980). Our investigations on DFF included all fractures of the distal third or distal 15 cm of femur thus separating the mostly extra-articular, supracondylar from the intra-articular unicondylar and bicondylar fractures (Fig 2). The term "supracondylar" was thus used exclusively for fractures not involving the articular joint surface. The subdivisions because of displacement was considered separately for the supracondylar, intercondylar and condylar parts of each fracture type. A few intra-articular fractures from severe trauma traversed the weight-bearing part of the femoro-tibial articulation and were considered separately (transcondylar fractures). All fractures in our investigations fell within the framework of this classification. Besides separating medial from lateral unicondylar fractures, Seinsheimer (1980) used the same principles. Neer et al (1967) found the direction of the displacement important. His material included only intra-articular fractures separated into four types. We found that transcondylar, intercondylar and supracondylar displacement are the essential components in the treatment, and prognosis while T, Y or V appearance and some of the subgroups used by Seinsheimer (1980) seemed to us of less importance.

The annual incidence of DFF over the age of 15 has not been described previously. It was found to be 51 per million inhabitants in Malmö. The mean age in consecutive materials ranged from 40 (Stewart et al 1966), to 55 (Neer et al 1967) compared to 65 in our

retrospective and 66 in our prospective series. In selected cases for surgery Slätis et al (1971) had a mean of 37, Benum (1977) of 75 years. The female proportion ranged from 0.4 to 1.0 (Table 2). Advanced age and dominance of females increases the incidence of bone fragility, important in the choice of treatment.

Stewart et al (1966) have collected the largest material of 422 consecutive DFF over 20 years. Neer et al (1967) presented 110 consecutive intra-articular fractures collected during 24 years. Our retrospective series comprised 137 DFF over an eight year period. Neer had 22 per cent, Trentz 25 per cent and we had 7 per cent open injuries while no figure was given in the materials of Stewart et al (1966) and Seinsheimer (1980). In 1970, 140 prospective DFF were presented by Mooney et al who randomized femoral fractures of the distal 2/3 for plaster or cast-brace after 7-8 weeks of traction. The special type of supracondylar fracture that follows Ender-nailing for trochanteric fractures is unusual, the risk has been estimated to be about 1 per cent (Passl et al 1975, Hult and Nilsson 1978). In our prospective series there were 4/54 such cases.

The proportion of patients treated surgically was found by Stewart et al to be 0.3, and by Neer et al to be 0.5 while we had 0.3 in our retrospective series and 0.6 in our prospective series. Indications for surgical and non-surgical treatment, however, are never fully comparable in different series and conclusions regarding treatment should only be drawn from comparable groups taking age, trauma and fracture types into account.

Surgical failures were reported by Schatzker and Lambert (1979) in 9/19 patients over 50 compared to 1/17 below 50 in fractures stabilized by condylar plates. Olerud (1972) also found difficulties in securing fractures in fragile bone with this method. Extra-articular DFF were stabilized with a condylar plate supplemented with acrylic cement in three fractures by Schatzker et al (1974) and in 14 fractures with extensive osteoporosis by Benum et al (1977) with

only one nonunion. Plating needs wider exposure and more time than pinning in general. Reports however, by Stewart et al (1966), Neer et al (1967) and Rush (1968) found the pins to migrate in osteoporotic bone thus resulting in insecure fixation. Zickel (1977) improved the condylar fixation with a new rod and a transcondylar screw at its distal end. Our semi-elastic fixation similarly intended to improve condylar fixation to make pinning possible.

Biomechanical tests were carried out to evaluate the efficiency of internal fixation achieved by different devices. The studies confirmed that the original stability of the condylar plate after mechanical overloading was lost and that semi-elastic fixation gave a better residual stability. Intra-medullary pins without distal screws (Rush, Ender) cut through the cancellous condylar bone losing its fixation. The clinical experiences with failure in cases with bone fragility were illustrated by these events. The degree of fragility in the specimens used, was not even always as pronounced in much of the clinical material.

Among general complications mortality is more dependent on general condition and concomitant injuries than on the fracture (Stewart et al 1966). Schatzker et al (1974) had four deaths among 47 supra-condylar cases equally distributed between surgical and non-surgical treatment. In our prospective series we had four deaths in 34 surgically treated. These deaths occurred after 2 weeks to 3 months from complications not involving the fracture in elderly women (gastric bleeding 1, cardio-pulmonary 2, cerebral damage after traffic accident 1).

Among local complications, vascular damage was found by Stewart (1966) to occur in 4/442, by Neer (1967) in 1/110 and by Trentz (1977) in 0/199. Trentz found three nerve lesions. In our studies there were no vascular damages and one peroneal palsy appeared (I).

With regard to infection Trentz et al (1977) had 7/199 cases of osteomyelitis in patients with severe trauma in 80 per cent and 25 per cent open fractures. Two were amputated 3.5 years later and two had an arthrodeses performed. Neer reported 10/110 fractures as infected in 22 per cent open injuries. Our retrospective series comprised 10/137 open fractures and four infected cases including one osteomyelitis. The last patient was amputated at eight months. In the prospective series with a fraction of 0.4 severe trauma in 34 surgical patients no infection resulted. Antibiotics were given only in open fractures, intra-articular fractures, after extended incisions, previous arthroplasty of the hip or operating time exceeding one hour.

The conclusions of Stewart, Neer and Benum that unstable internal fixation could imply a great risk of infection is contradicted by our experiences. It is more probable that the large exposure required for applying plates increases the risk of infection. Additionally in some cases such plating can prevent bone contact. The slight shortening (mean 1.4 cm) appearing in many of our cases is well compensated for by the reliable healing. Contrary to plates, intramedullary nails do not cause bone atrophy requiring restricted weight-bearing following removal.

Delayed union was reported by Neer et al (1967) in 11/74 fractures when stability and radiographic callus were not evident at 16 weeks. Stewart et al (1966) had 34/213 and Trentz et al (1977) had 21/199 after 24 weeks. Mooney et al (1970) found six non-unions in 50 patients treated in long leg plaster and none in 150 treated in a cast-brace. Seventy per cent of these fractures were situated in the distal third, the remainder in the midshaft. Traction for 7-8 weeks preceded the plaster or cast-brace. Our prospective series showed only 1/29 non-union following surgery and our retrospective 5/137. A time limit of 16 weeks for delayed union was used for the cancellous bone of the distal 8 cm (Neer et al 1967) while 24 weeks was used when the cortical bone of the distal third of femur was considered (Trentz et al 1977).

Deformities of the united fractures were found by Neer et al. (1967) in 11/74. Stewart et al (1966) found that valgus and flexion deformity of the distal fragment was most common. Trentz et al (1977) found 22 varus, 14 valgus and 10 recurvations in 164 re-examined patients. We found varus and anterior angulation after bicondylar and varus after supracondylar fractures to be the most common deformities. The exact calculation of the true angle of deformity, used in our re-examination does not appear in other materials, and thereby could not be compared.

Knee function was classified by Stewart et al (1966) based on pain, range of motion, angular deformity and arthrosis. Neer et al (1967), Olerud (1972) and Trentz et al (1977) used 70 functional and 30 anatomical points while we used simple criterias similar to Stewart in our papers I and IV. In our prospective series (IV) in addition the patients were asked about their own opinion regarding the results which correlated well to the assessment. In the series re-examined for late function (II) the Knee Disability Sheet (Ranawat et al 1976) was used because of its evaluation of range of motion which we considered important following fracture treatment. The small groups and frequency of previous diseases only confirmed that the bicondylar fracture with transcondylar engagement was worse than the others.

Arthrosis of the knee joint was judged from the radiograms by Stewart et al (1966) and by Neer et al (1967) but without staging or separation of the different articulations. Our re-examination (II) with a mean observation time of five years demonstrated arthrosis separately for 3/51 in the femoro-tibial articulation and 14/51 in the patellar articulation. All three with femoro-tibial arthrosis had concomitant patellar arthrosis. According to Ahlbäck (1971) all were stage I or II. Intercondylar diastasis or alteration in condylar level exceeding 3 mm significantly increased the risk of arthrosis. The mean time of five years (range 2-10 years) at re-examination did not reveal arthrosis from angular deviation in

supracondylar, extra-articular fractures which probably takes longer to develop. In 212 consecutive high tibial osteotomies Tjörnstrand (1981) found one supracondylar and one femoral shaft fracture proceeding to arthrosis 15 and 20 years respectively after injury. An axial projection of the patellar joint should be taken to demonstrate fracture engagement of the femoro-patellar articulation as this evidently was commonly disturbed, which has not been demonstrated before.

The mean hospital stay for patients treated in traction was 62 days and 33 days for surgical cases in the material by Stewart et al (1976). The mean age in his series was 40 years compared to 65 in ours. The mean hospital stay in our retrospective series was 56 days for supracondylar and 63 days for bicondylar fractures while unicondylar stayed 14 days. In our prospective series the total mean hospital time was 40 days. Because of the differences in age, fracture types and social circumstances, comparisons of hospital stay in these materials are of limited value.

The semi-elastic fixation device seems advantageous for patients with bone fragility. Because of the small number of patients without bone fragility in our series no comparison can be made between the results of the semi-elastic fixation and rigid internal fixation for this group. It is possible that rigid fixation will allow for more unrestricted mobility at the price of wider exposure and somewhat higher risk of delayed union and infection.

GENERAL SUMMARY

The purpose of this work was to introduce a new fixation device for distal femoral fractures at the Department of Orthopaedic Surgery in Lund, and to study the results of this program. The incitement was the unsatisfactory outcome of treatment as gleaned from the literature (Stewart et al 1966, Neer et al 1967, Schatzker et al 1974, 1979) and our own experience. The basis was one retrospective epidemiological study of a consecutive patient group and one radiographic and clinical re-examination of the late results among these patients.

The review of 137 patients treated at the Departments of Orthopaedic Surgery in Lund and Malmö revealed that 84 per cent were over age 50 and additionally more than half had diseases or previous fractures contributing to bone fragility. The treatment of all the unicondylar fractures and the undisplaced bicondylar and supracondylar fractures seemed satisfactory and allowed for early mobilization. The treatment of the displaced supracondylar and bicondylar fractures showed a mean of seven weeks in traction for 47 patients treated nonsurgically while the surgical treatment failed in 13 patients.

Sixty-two of these patients were re-examined with a mean observation of five years. A classification into supracondylar, unicondylar and bicondylar fractures was proposed with subdivisions according to the degree of supracondylar, intercondylar and transcondylar displacement. Intercondylar and transcondylar diastasis and disturbance of the joint level for the bicondylar fractures caused most of the unsatisfactory results and early gonarthrosis developed mostly in these groups. Attention was paid to the examination of the patellar joint by axial projections. The importance of anatomical reduction and firm fixation of the condyles was stressed.

In a biomechanical test series on 17 pairs of post-mortem femoral preparations, including the knee and tibia, loadings in extension

and abduction were performed. An osteotomy was made 6 cm above the knee joint level and five internal fixation devices were tested; two in each pair of specimen from the same individual. It was concluded that the AO condylar plate was the strongest, showing the least flexibility but also the least residual strength after overloading. The heads of the Rush pins cut through the cancellous bone losing their distal fixation. The rather stiff blade-shaped Zickel rod did not adapt to the curvature of the femoral shaft and occasionally caused displacement of the fracture. The semi-elastic device maintained the distal stability when loaded and allowed elastic adjustment to the shaft, retaining bone contact after loading.

In a prospective series of supracondylar and bicondylar femoral fractures 1978-1980, 15 undisplaced fractures were treated in plaster and cast-brace and 34 displaced fractures in cast-brace after surgical semi-elastic fixation. The mean age for the surgical group was 65 years and only eight were previously healthy. The operation was performed through small incisions on each side of the knee on a traction table with the knee flexed and the use of an image intensifier. The follow up of the surgical group showed 12 excellent, 9 good, 5 fair and 3 poor results. There was no infection and only one delayed union.

SUMMARIZED PRINCIPLES OF TREATMENT

It is concluded that patients with undisplaced DFF should be mobilized immediately in plaster followed by cast-brace after two weeks. Displaced DFF should be stabilized by surgery; unicondylar by internal screw fixation and supracondylar and bicondylar fractures with fragile bone with semi-elastic fixation. The small group of patients with healthy bone and supracondylar and bicondylar displaced fractures also showed satisfactory results with this method. The fixation should pay careful attention to the anatomical reduction of intercondylar and transcondylar displacement. Immediate mobilization with anterior plaster slab, followed by hinged cast-brace after two weeks is recommended.

CONCLUSIONS

1. About four per cent of all femoral fractures appear in the distal third.
2. Over 80 per cent of the patients were over 50 years of age and more than half had in addition bone fragility of the injured side because of previous or current disease.
3. Distal femoral fractures should be separated into supracondylar, bicondylar and unicondylar fractures and subdivided according to displacement. Transcondylar displacement (through weight-bearing articular surface) caused early arthrosis.
4. Of several internal fixation devices tested biomechanically, the condylar angle plate was shown to have the greatest strength but caused fractures at overload and the semi-elastic fixation was stable in the condyles in contrast to the Rush pin and Ender nails which cut through. After maximal loading the semi-elastic device retained its strength.
5. Surgical treatment was used in 35/105 in the retrospective and 34/54 in the prospective group of supracondylar and bicondylar fractures. Traction in bed was reduced from 47/104 to 6/54.
6. Displacement with a resultant uneven articular surface should be corrected surgically. Other displaced fractures should be stabilized by surgery if traction in bed is the alternative.
7. The semi-elastic fixation device combined easy insertion with sufficient stability to allow for early mobilization. At follow up the range of motion had almost reached the pre-fracture level. Infection and delayed union were less frequent than in other published series and shortening more than 2.5 cm occurred in 6/29, the mean being 1.4 cm.

8. When a supracondylar femoral fracture complicated Ender-nailing for a trochanteric fracture 5/7 run obliquely in a proximo-lateral direction. The semi-elastic device was useful for this complication.

ACKNOWLEDGEMENTS

I wish to express my gratitude to:

The patients who participated in this investigation as well as the staff and my colleagues of the Departments of Orthopaedic Surgery and Diagnostic Radiology in Lund, Malmö, Helsingborg, Ängelholm, Landskrona, Ystad and Trelleborg.

Jeanette Stenelo for typing the manuscript.

K G Thorngren, M.D. for statistical advise.

Pehr Johnson and Göran Eliasson for the photographic work.

David Haffajee, M.D. for carefully revising the manuscript for English composition and syntax.

Financial support was provided by grants from:

Förenade Liv Mutual Insurance Company, Stockholm, Sweden

Stiftelsen för Bistånd åt Vanföra i Skåne

Alfred Österlunds Stiftelse

Swedish Medical Research Council (Project 17X-2031)

REFERENCES

- Acrel, O.: Chirurgiska Händelser. First edition, Stockholm 1759.
- Adams, J.C.: Outline of fractures. E & E Livingstone, London 1968.
- Ahlbäck, S.-O.: Osteoarthritis of the knee. A radiographic investigation. Thesis Stockholm. Acta Radiologica Suppl 277, 1971.
- Benum, P.: The use of bone cement as an adjunct to internal fixation of supracondylar fractures of osteoporotic femurs. Acta Orthop Scand 48 (1): 52-56, May 1977.
- Böhler, N., Kuderna, H.: Ergebnisse der Endernagelung in Österreich unter spezieller Berücksichtigung der Fälle des Lorenz-Böhler-Krankenhauses. Arch Orthop 88: 339-346, 1977.
- Campbells Operative Orthopaedics. Sixth Edition 587-594. C.V. Mosby Company, St Louis, Toronto, London 1980.
- Chiron, H.S., Trémoulet, J., Casey, P. and Müller, M.: Fractures of the distal third of the femur treated by internal fixation. Clin Orthop 100: 160-170, 1974.
- Cooper, A.: A treatise on dislocations and on fractures of the joints. Fourth edition, London 1824.
- Danis, R.: Théorie et pratique de l'osteosynthèse. Masson, Paris 1949.
- Hult, L., Nilsson, M.H.: Enderspikning av trochantära femurfrakturer. Läkartidningen 75: 4603- 4608, 1978.
- Judet, R.: Fractures de l'extrémité inférieure du fémur. Act Orthop Belg 36: 596-600, 1970.
- Kirschner, M.: Über Nagelextension, Beiträge zur Klinische Chirurgie 64: 266, 1909.
- Kolmert, L., Persson, B.M.: Två sorters Zickelspik för femurfraktur, proximalt respektive distalt. Med Riksstämman, Stockholm 1978.
- Kolmert, L., Persson, B.M.: Semi-elastisk osteosyntes av distala femur frakturer - en ny teknik. Med Riksstämman 1980.

- Küntscher, G.B.G.: Praxis der Marknagelung, F K Schattauer Verlag, Stuttgart, 1962.
- Mahorner, H.R. and Bradburn, M.: Fractures of the femur. Surg Gyn and Obst 56: 1066-79, 1933.
- Modlin, J.: Double skeletal traction in battle fractures of the lower femur. Bull U S Army Med Dept, No 4: 119-120, 1945.
- Mooney, V., Nickel, L.V., Harvey, J.P. and Snelson, R.: Cast-brace treatment for fractures of the distal part of the femur. J Bone Jt Surg 52-A: 1563-1578, 1970.
- Müller, M.E., Allgöwer, M. and Willenegger, H.: Manual of internal fixation. New York, Springer Verlag 1970.
- Neer, C.S., Grantham, S.A. and Shelton, M.L.: Supracondylar fractures of the adult femur. A study of 110 cases. J Bone Jt Surg 49-A: 591, 1967.
- Olerud, S.: Operative treatment of supracondylar - condylar fractures of the femur. J Bone Jt Surg 54-A: 1015, 1972.
- Passl, R., Martinek, H., Paar, O., Spängler, H.: Ergebnisse der Fixierung perthrochanterer Frakturen mit Kondylennägeln nach Ender und Simon-Weidner. Chirurg 46: 568-571, 1975.
- Ranawat, C.S., Insall, J. and Shine, J.: Duo condylar knee arthroplasty. Clin Orthop 120: 76-82, 1976.
- Rush, L.V. and Rush, H.L.: A technique for longitudinal pin fixation of certain fractures of the ulna and of the femur. J Bone Jt Surg 21: 619-626, 1939.
- Rush, L.V.: Atlas of Rush pin technics. Berivon Co 1955.
- Rush, L.V.: Dynamic intramedullary fracture fixation of the femur. Clin Orthop 60: 21-27, 1968.
- Schatzker, J., Horne, G. and Waddel, J.: The Toronto experience with supracondylar fracture of the femur. Injury 6: 113-128, 1974.

- Schatzker, J. and Lambert, D.C.: Supracondylar fractures of the femur. Clin Orthop 138: 77-83, 1979.
- Seinsheimer, F.: Fractures of the distal femur. Clin Orthop 153: 169-179, 1980.
- Shelton, M.L., Grantham, S.A. and Neer, C.S. and Singh, R.: A new fixation device for supracondylar and low femoral shaft fractures. J Trauma 14: 821-835, 1974.
- Slätis, P., Ryöppy, S. and Huittinen, V.M.: AOI osteosynthesis of fractures of the distal third of femur. Acta Orthop Scand 42: 162, 1971.
- Steinmann, F. von: Eine neue Extensionsmethode in der Frakturbehandlung (Vorläufige Mitteilung). Zentralblatt f. Chirurgie: 32, 838, 1907.
- Stewart, M.J., Sisk, T.D. and Wallace, S.L.: Fractures of the distal third of the femur: A comparison of methods and treatment. J Bone Jt Surg 48-A: 784-807, 1966.
- Trentz, O., Tscherne, H. and Oestern, H.J.: Operationstechnik und Ergebnisse bei distalen Femur Frakturen. Unfallheilkunde 80: 441-448, 1977.
- Umansky, A.L.: Blade-plate internal fixation for fracture of the distal end of femur. Bull Hosp Joint Dis 9: 18-21, 1948.
- Vidal, J., Dimeglio, A. and Buscayret, C.: Nos indications dans le traitement chirurgicale des fractures supra-condyliennes du fémur. J Chir (Paris), 111: 561-572, 1976.
- Watson-Jones. R.: Fractures and joint injuries. Churchill-Livingstone, London 1976.
- Zickel, R.E., Fietti, V.G., Lawsing, J.F. and Cochran, G.V.B.: A new intramedullary fixation device for the distal third of the femur. Clin Orthop 125: 185-191, 1977.
- Önnerfält, R.: Fracture of the tibial shaft treated by primary operation and early weight-bearing. Thesis Lund. Acta Orthop Suppl 171, Munksgaard 1978.

EPIDEMIOLOGY AND TREATMENT OF DISTAL FEMORAL
FRACTURES IN ADULTS

by

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ABSTRACT

Fractures of the distal femur constitute 4 per cent of all femoral fractures. A consecutive series from 1969 through 1976 of 135 adult patients with 137 fractures not caused by malignant disease, were reviewed for age, sex, previous disease, type of fracture, treatment and end result. Eighty-four per cent of the patients were over 50 years; 19 per cent had other general factors predisposing to fracture. Fourty-two per cent had previous or current disease of the fractured leg.

Eighty-three fractures were caused by moderate trauma and 52 by severe. Unicondylar fractures were separated into lateral or medial type. Ten fractures were open. Fourty-five fractures were operated on primarily, mostly with condylar plates, screws or Rush pins.

The results were satisfactory (painless knee without angular deformity and at least 90° of motion) in two thirds following both non-surgical and surgical treatment. However, the surgical group was on an average eight years younger and showed a higher proportion of bicondylar fractures than the non-surgical. The treatment in traction showed a mean of seven weeks for 47 patients. This expensive mode of treatment does not exist for femoral neck, trochanteric and shaft fractures today. Correspondingly for the distal femoral fractures the goal should be early mobilization, attained if necessary, by surgical treatment.

INTRODUCTION

Stewart et al (1966)¹¹ claimed that "fractures in the distal third of the femur continue to perplex the surgeon. Whether they are transverse, oblique, or comminuted, or supracondylar or intercondylar in a T, Y or V fashion their management still evokes much controversy because of the consistently poor results obtained". This study con-

Key words: Distal, Supracondylar, Femoral, Fracture, Epidemiology, Etiology, Result, Treatment.

cerns fractures of the distal third of femur in adults unsuitable for intramedullary drilling and fixation according to Küntscher. Fractures in malignant bone disease and osteochondral fractures were excluded.

METHODS

The investigation was based on all patients over age 16 with supra-, uni- and bicondylar fractures treated 1969 through 1976 at the Departments of Orthopaedic Surgery of the University Hospitals in Lund and Malmö.

Via the WHO-data registrations at the hospitals 194 patients were identified. The radiographic films had been examined by radiologists and were reexamined by the authors and discussed again in doubtful cases with the radiologist. After the exclusion of patients who had received primary treatment in other hospitals and patients with missing or incomplete radiographic examinations and records, 55 patients with 56 distal femoral fractures were included from Lund and 80 patients with 81 fractures from Malmö making a total of 135 patients with 137 fractures.

Lund is a regional centre and therefore receives patients from other hospitals as well. Malmö is a city of around 250.000 inhabitants and has only one orthopaedic department which does not receive fractures from without the city; the fractures in Malmö were therefore used for incidence assessment. The incidence of fractures in Malmö has previously been presented for the forearm by Alffram and Bauer (1962),² the hip by Alffram (1964)¹ and the ankle by Nilsson (1967).¹⁰

In order to study characteristics in patients who sustained distal femoral fractures the Malmö material was combined with the Lund material. The patients and fractures were classified according to sex, age, side, fracture type (supra-, uni- and bicondylar), previous diseases (local and general), moderate and severe trauma, treatment and final result.

The degree of violence was assessed as severe or moderate according to Alffram and Bauer (1962).² Severe trauma was defined as that resulting from a more severe fall than from a standing position. Thus all traffic accidents, fall on stairways or fall from standing on a chair were considered severe. Two patients, who sustained their fractures when the knee hit the rink during skating, were also classified as severe. Falls on the ground or from sitting on a chair or lying in bed were classified as moderate.

Optimal treatment should completely restore the leg with regard to position and function within the shortest time possible without complications and at reasonable costs. The detailed pre-operative assessment of limb function, as used prior to hip and knee replacement surgery, is unfortunately impossible to achieve when judging the outcome of fracture treatment. This material comprises aged patients with a high percentage of previous diseases in the fractured leg, sometimes in the other leg and sometimes with other disabilities making the pre-fracture state more difficult to evaluate than in previously healthy patients. Information concerning the final results in the records is sometimes insufficient and we have for this reason excluded 13 patients in the non-surgical group and four in the surgical. Three patients died shortly after sustaining their fracture and before healing and were not included. We assessed the results with regard to knee motion, pain, angular deformity and shortening (Table 1).

The result was reduced from "excellent" to "good" if one of the criterias for "good" was fulfilled etc. Two or more of the criterias for "good" reduced the result to "fair". Two or more of the criterias in the "fair" group reduced the result to "poor". The staging of the results is modified after Stewart et al (1966),¹¹ concerning pain, angular deformity and shortening. Due to the shorter observation time and the number of elderly patients with previous diseases and limited needs of function we have accepted somewhat further limitations in range of motion. Some of the patients were

using waking sticks or crutches, for which the reason is not always apparent in this age group and this criteria is therefor avoided for classification purposes. Patients operated for non-union were considered as failures and the results classified as "poor". We have taken the known pre-operative function into consideration in this assessment, i.e. a patient using a wheel-chair before fracturing his leg was classified as excellent if he was sitting comfortably without pain, although the fracture might have healed in slight malposition or with some shortening. "Excellent" and "good" were considered as satisfactory and "fair" and "poor" as unsatisfactory.

Table 1. Classification of results after distal femoral fractures.

Result	Knee motion	Pain	Angular deformity	Shortening
Satisfactory:				
<u>Excellent</u>	Full extension and 120° of flexion	None	None	Less than 1 cm
<u>Good</u>	Full extension and 90° of flexion	None or occasionally	Hardly visible	Less than 2 cm
Unsatisfactory:				
<u>Fair</u>	Less than 10° extension defect, more than 60° of total motion	Slight pain always	Less than 10° of varus or valgus	Less than 3 cm
<u>Poor</u>	10° extension defect. Less than 60° of total range of motion	Constant and severe	10° varus or valgus or more	More than 3 cm

RESULTS

Fracture incidence. The annual number of distal femoral fractures in Malmö ranged from 6 to 15 with an average of 10.1 ± 6.0 ($M \pm 2sd$) corresponding to an annual incidence of 51 per million inhabitants over 16 years.

Age and sex distribution (Fig 1). Eighty-four per cent of the fractures occurred after age 50. Males dominated in the youngest age groups and females in the oldest; only 10 of 78 fractures after age 65 occurred in males. The age pattern was similar in the different fracture types.

Table 2. Number of patients with impaired function in both legs due to previous fractures or generalized diseases.

Hip fractures (bilateral)	1
Gonarthrosis (bilateral)	8
Polio	4
Epilepsy	3
Cerebro-vascular disease	3
Rheumatoid arthritis	1
Coxarthrosis (bilateral)	1
Cortisone treatment (astma bronchiale)	1
Multiple sclerosis	1
Haemophilia	1
Stomach resection (Billroth II)	2
Total	26

Other predisposing factors. Twenty-six patients had impaired function in both legs (Table 2) from diseases which probably contributed to the fracture. As the influence on bone strength from diabetes and Parkinson's disease is not proved, these diseases were not considered. Fifty-seven patients had sustained their fractures in the leg where they had had other fractures or diseases (Table 3).

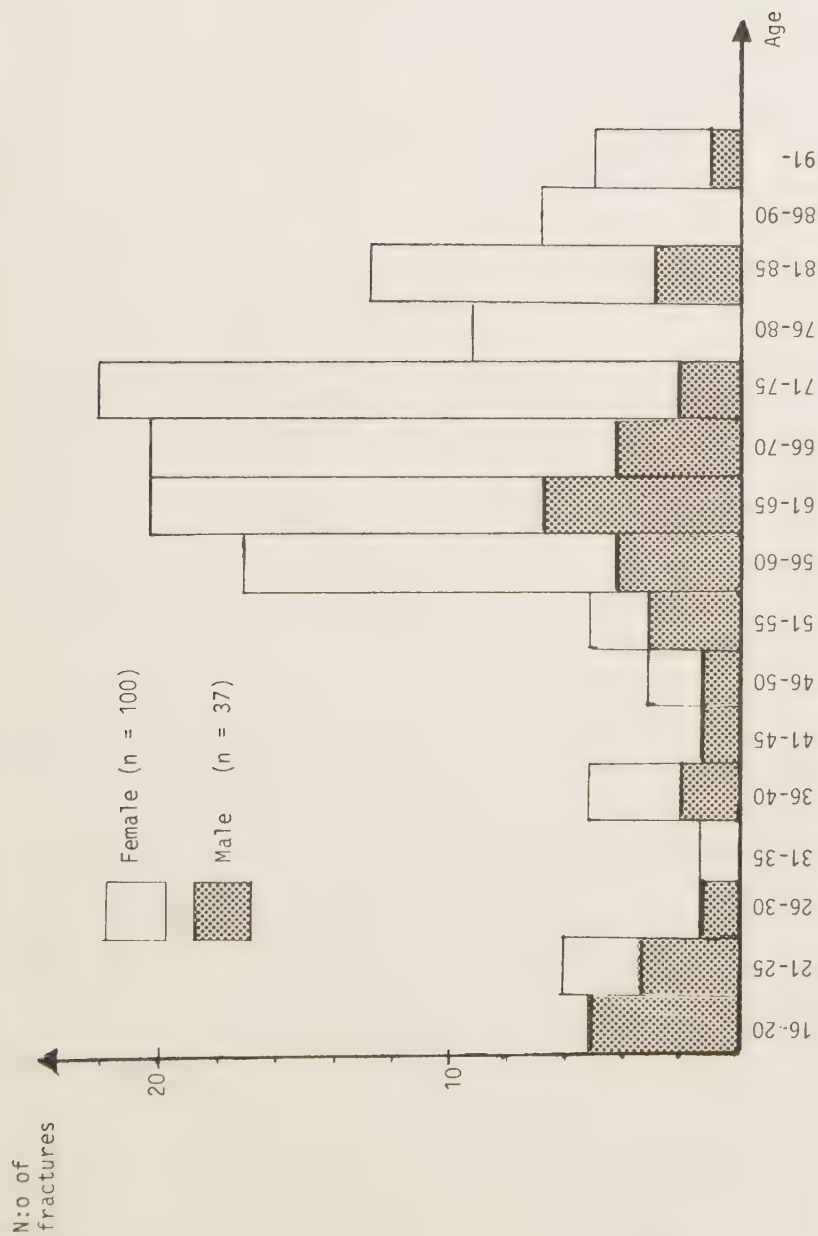


Fig 1. Age and sex distribution of distal femoral fractures.

Mean age 65 years. Median age 68 years.

Table 3. Number of patients with impaired function in fractured leg due to previous fractures or diseases.

Pelvic, femoral neck and trochanteric fractures	24
Other fractures of femur and lower leg	17
Coxarthrosis (unilateral)	5
Congenital disease of hip	2
Perthes disease	1
Hip arthrodesis after TBC	1
Lower leg amputation	3
Gonarthrosis (unilateral)	1
Osteochondritis dissecans	1
Knee arthrodesis	1
Congenital deformity of the leg	1
Total	57

Only one patient with a previous hip fracture, fractured the healthy, contralateral leg. Thus a highly significant ($p < 0.001$)* proportion of the patients had impaired function with a weakened skeleton and/or decreased neuro-muscular function in the fractured leg. The greatest number of previous fractures was seen in the hip in the elderly. The incidence of hip fractures is higher ($p < 0.05$)* in patients with distal femoral fractures compared to the normal population.

Trauma (Table 4). One third of the fractures was caused by severe trauma and two thirds by moderate trauma. Ten fractures were open. The proportion of severe trauma (mostly traffic accidents) was highest in the young age groups. Supracondylar fracture in 33 of 39 patients had moderate trauma which was highly significant ($p < 0.001$)* compared to the bicondylar group. The supracondylar fracture patient was eight years older ($p < 0.05$)* than the bicondylar and four years older than the unicondylar fracture patient. There was no conclusive difference in number, type and degree of trauma between lateral and medial unicondylar fractures. Three osteoporotic patients with unicondylar fractures caused by moderate trauma had a concomitant malleolar fracture of the same lateral or medial side.

* Statistical analysis by Chi-square test with Yate's correction.

Table 4. Distal femoral fractures classified according to anatomical type, age and violence.

Type	n	Mean age	Moderate trauma	Severe trauma	Unknown trauma
Uni-C	33	65	21 (0.66)	11 (0.34)	1
Bi-C	65	61	29 (0.45)	35 (0.55)	1
Supra-C	39	69	33 (0.85)	6 (0.15)	-
Total	137	65	83	52	2

Results of treatment (Table 5 and 6). The results are acceptable (excellent or good) in about 2/3 of all fractures after both surgical and non-surgical treatment. The outcome of non-surgical treatment was satisfactory in 19/22 unicondylar fractures, in 24/35 bicondylar fractures and in 15/22 supracondylar fractures. The mean time in traction was 7.3 weeks for bicondylar and 6.6 weeks for supracondylar fractures. Surgical treatment was satisfactory in 28 fractures and unsatisfactory in 13 (Table 5). Surgical methods employed were condylar plates in four patients, Rush pins in four and screws in five in the unsatisfactory group. The unicondylar group showed only one unsatisfactory result, probably a result of soft tissue damage. Thus 12/13 unsatisfactory were bi- or supracondylar fractures and all unsatisfactory were over 50 years.

The complications (Table 7) were one infection, three re-fractures and two non-unions in the non-surgical group compared to four infections of which one resulted in osteomyelitis, three non-unions and one broken plate in the surgical group.

The mobilization time following distal femoral fractures (Table 8) was longest for the bi- and supracondylar fractures.

Table 5. Results of non-surgical treatment according to type of fracture, treatment and age.

Treatment	Age over 50	Uni-C		Bi-C		Supra-C		Unknown results
		Exc+ good	Fair+ poor	Exc+ good	Fair+ poor	Exc+ good	Fair+ poor	
Traction	-	-	-	4	1	-	1	-
	+	-	-	10	3	4	3	3
Traction and plaster	-	-	-	-	1	-	-	-
	+	-	-	6	4	4	1	4
Plaster only	-	2	-	-	1	1	-	-
	+	16	3	4	1	4	1	6
Non-Weight bearing	-	1	-	-	-	-	-	-
	+	-	-	-	-	-	2	1
Bed-rest	+	-	-	-	-	2	1	
Total		19	3	24	11	15	7	13

Table 6. Results of surgical treatment according to type of fracture, treatment and age.

Treatment	Age over 50	Uni-C		Bi-C+Supra-C		Unknown results
		Exc+ good	Fair+ poor	Exc+ good	Fair+ poor	
AO-plate	-	-	-	4	-	-
	+	-	-	9	4	2
Rush pin	-	-	-	-	-	-
	+	-	-	1	4	1
Screws	-	-	-	2	1	-
	+	5	1	2	3	1
Other	-	2*	-	1**	-	-
	+	2***	-	-	-	-
Total surgical		9	1	19	12	4

* Staples 1, Nails 1

** Thornton nail and plate 1

*** Staples 1, Wright-plate 1

Table 7. Complications of non-surgical and surgical treatment according to fracture type.

Complication	T r e a t m e n t					
	Non-surgical			Surgical		
	Uni-C	Bi-C	Supra-C	Uni-C	Bi-C	Supra-C
Death						
Cardiac disease		2				
Meningioma						1
Non-fatal DIC*- syndrom	1		1			
G-i bleeding** (Anti-coagul)					1	
Peroneal palsy	1					
Infection		1		1	2	
Osteomyelitis					1***	
Refracture		1	2			
Non-union		1	1		1	2
Broken plate					1	

* DIC = Disseminated Intravascular Coagulation

** G-i = Gastro-intestinal

*** Amputated after 8 months

Table 8. Mobilization following distal femoral fractures.
Time in weeks for 0.5 and 0.9 of the patients.

Type	0.5 of patients			0.9 of patients		
	Walking	Discharged hospital	Full weight	Walking	Discharged hospital	Full weight
Uni-C	1	2	8	6	10	14
Bi-C	7	8	12	11	17	22
Supra-C	5	9	12	12	19	22

DISCUSSION

Conservative treatment in tibial traction for distal femoral fracture was reported by Mahorner and Bradborn (1933),⁶ with good final results in only a few cases. Tibial traction was supplemented by femoral vertical traction to balance the pull of the gastrocnemius muscle and the results reported by Modlin (1945)⁷ were encouraging. The retrospective reports by Stewart et al (1966)¹¹ and Neer et al (1967)⁹ favoured simple non-operative methods of treatment. However, new surgical methods and materials (Zickel et al 1977,¹² Müller et al 1979)⁸ have improved the results of surgery.

Because of the high percentage of elderly patients with previous diseases, results in this material cannot directly be compared to other reviews of young patients with healthy skeleton and fractures sustained by high energy.

Classification for fractures in the distal third of the femur was somewhat different in previous reports. Chiron et al (1974)³ and Stewart et al (1976)¹¹ divided the fractures into uni- and supra-, and T-fractures (intercondylar), while Neer et al (1967),⁹ omitted the first two groups and described four stages of T-fractures. His classification is based on the direction and displacement of the femoral shaft and the corresponding damage to the soft tissues.

Our fractures were classified in supra-, uni- and bicondylar. The supracondylar fracture is extra-articular with regard to articular cartilage but might involve the supra-patellar pouch. The uni- and bicondylar fractures are intra-articular and involve the patellar joint and the congruence of the two condyles. Treatment of the uni-condylar fracture consists of apposition of the separated condyle to each other, whereas in bicondylar fractures the two condyles first have to be apposed before the supracondylar fracture can be treated. This classification is preferred because it gives a simple, verbally correct description of the fracture and simultaneously suggesting the treatment. The term supracondylar fracture should

thus never be used synonymously with other types of distal femoral fractures. We have avoided subdivisions of the distal femoral fractures in this work concerning primary results, but have made a further classification into non-displaced, displaced and transcndylar when examining late function and gonarthrosis for these patients (Egund and Kolmert).⁴ From the WHO-registrations in Malmö the over all ratio of different levels of fractures of the femur during a ten-year period (1969-1978) showed 4 per cent of 4.007 fractures to be in the distal third, 10 per cent were seen in the shaft and 86 per cent in the proximal third. Thus the infrequency of distal femoral fractures means limited experience for most orthopaedic surgeons regarding both classification and treatment.

The non-surgical treatment shows a total of 333 weeks in traction for 47 supra- and bicondylar fractures with a mean of 6.6 respectively 7.3 weeks. Fifty per cent of all the patients left hospital after 8-9 weeks which corresponds most probably to the average time of 62 days for hospital stay described by Stewart et al (1966).¹¹ In our clinic treatment in traction is not advocated for proximal and transverse shaft fractures of the femur. Surgical stabilization, available for elderly patients with little risk because of modern anaesthesiology, should probably be considered more frequently for fractures of the distal third. This could probably avoid some of the complications such as re-fracture and non-union, reduce the costs for hospital treatment and increase the possibilities of early mobilization.

The surgical treatment of bi- and supracondylar fractures showed unsatisfactory results after age 50 in 4/13 for the AO condylar plate, 4/5 for the Rush pin fixation and 3/5 for screws. Failures with non-union, broken plate and infection all occurred in the elderly. It is of great importance that osteosynthetic devices in these ages apply and adjust well to a fragile skeleton. The AO condylar plate requires wide exposure and is difficult to apply

(Müller et al 1979).⁸ As this is a fracture seldomly surgically treated by the orthopaedic surgeon the anatomic reduction and consequent internal rigid fixation might be difficult to attain. There is also the risk that the plate is stronger than the skeleton in the elderly and will cut. The commonly used Rush pin is easy to apply but may lose its distal insertion by cutting through the condyle with malposition of the fracture leading to an unsatisfactory final result. Fixation by screws only, were also unsuccessful. Below the age of 50 there was only one unsatisfactory result; improper fixation by screws in an oblique fracture of the lower femoral shaft necessitating 6 weeks of traction postoperatively. Roughly the results were satisfactory (excellent or good) in 2/3 of all fractures after both surgical and non-surgical treatment.

It was concluded from this material of elderly patients with previous diseases that it would be of benefit to stabilize the fracture immediately so as to avoid traction treatment in bed. The goal should be to mobilize patients with undisplaced fractures directly and those with displaced fractures immediately after operation in a suitable plaster or cast brace. The operative treatment and osteosynthetic devices must be adjusted to the patient, the soft tissue and the bone quality for an acceptable final outcome (Kolmert and Persson 1980).⁵ A new osteosynthetic device, designed especially for the fragile skeleton, was therefore developed in Lund. It consists of screws for rigid fixation of the intra-articular part of the fracture which are connected to intramedullary nails for elastic adjustment to the femoral shaft. This has been in clinical use since October 1978.

ACKNOWLEDGEMENTS

The statistical analysis was done by Karl-Göran Thorngren. Financial support for this study was provided by grants from Förenade Liv, (Mutual Insurance Company), Stockholm, Sweden.

REFERENCES

1. Alffram, P.A.: An epidemiologic study of cervical and trochanteric fractures of the femur in an urban population. Thesis. Acta Orthop Scand Suppl n:o 65, 1964.
2. Alffram, P.-A., Bauer, G.C.H.: Epidemiology of fractures of the forearm. J Bone Jt Surg 44-A: 105-114, 1962.
3. Chiron, H.S., Tremoulet, J., Casey, P., Müller, M.: Fractures of the distal third of the femur treated by internal fixation. Clin Orthop 100: 160-140, 1974.
4. Egund, N., Kolmert, L.: Deformities, gonarthrosis and function after distal femoral fractures. Accepted for publication in Acta Orthop Scand.
5. Kolmert, L., Persson, B.M.: Supracondylar femoral fracture as a complication to Ender-nailing of trochanteric fractures. Arch Orthop Traumat Surg 97: 51-55, 1980.
6. Mahorner, H.R. & Bradburn, M.: Fractures of the femur. Report of 308 cases. Surgery Gynecology and Obstetrics 56: 1066-1079, 1933.
7. Modlin, J: Double skeletal traction in battle fractures of the lower femur. Bull U.S. Army Med, Department 4, 119-120, 1945.
8. Müller, M.E., Allgöwer, M., Willenegger, H.: Manual of internal fixation. Springer Verlag, Berlin and New York, 1979.
9. Neer, L.S. II, Grantham, S.A., Shelton, M.L.: Supracondylar fractures of the adult femur. J Bone Jt Surg 49-A: 591-613, 1967.
10. Nilsson, B.E.R.: Age and sex incidence of ankle fractures. Acta Orthop Scand 40: 122-169, 1969.
11. Stewart, M.J., Sisk, T.D., Wallace, S.L.: Fractures of the distal third of the femur. J Bone Jt Surg 48-A: 784-807, 1966.

12. Zickel, R.E., Fietti, B.G. Jr, Lawsing, J.F., Cochran, G.V.B.:
A new intramedullary fixation device for the distal third of
femur. Clin Orthop 125: 185-191, 1977.

DEFORMITIES, GONARTHROSIS AND FUNCTION AFTER
DISTAL FEMORAL FRACTURES

by

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ABSTRACT

Sixty-two distal femoral fractures from 1969-1976 were re-examined, with a mean follow-up of five years, to study resultant deformities, gonarthrosis and function. These fractures occur mainly in the elderly with bone fragility from age and disease. The deformities were analysed in precisely defined radiographic projections. An anatomical classification into supra-, uni-, and bicondylar fracture with subdivisions into undisplaced and displaced was used, with a special group for transcondylar fractures.

Deformed bicondylar fractures healed mostly in varus and anterior angulation, medial unicondylar in varus and lateral unicondylar in valgus. The healed supracondylar fractures mostly showed varus-angulation. Three patients developed arthrosis in both femoro-tibial and patellar articulations, eleven only in the latter. Inter- or transcondylar diastasis or difference of level in joint surface exceeding 3 mm significantly caused arthrosis.

The function was assessed according to Ranawat et al (1973).¹⁶ The radiographic examination of the patellar joint in the axial projection at the time of admission is stressed. Exact reduction and sufficient stabilization of the intraarticular fractures seem important in reducing arthrosis and late impairment of function.

INTRODUCTION

Fractures of the distal third of the femur comprises 4 per cent of all femoral fractures (Kolmert and Wulff).⁹ Experience in the treatment of this fracture is therefore limited and only few reports mention the primary displacement after fracture and the deformities in the healed fractures (Modlin 1945, Stewart et al 1966, Neer et al 1967, Schatzker et al 1974, Trentz et al 1977, Della Torre 1980).

Key words: Function, deformities, gonarthrosis, osteoarthritis, distal femoral fracture, supracondylar fracture, radiologic examination.

The aim of this study was to describe deformities following healing, estimate arthrosis (osteoarthritis) separately in the femoro-tibial and the patellar articulations and assess function and its relation to deformities and arthrosis.

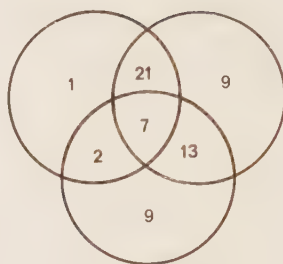
METHODS

At the Departments of Orthopaedic Surgery in Lund and Malmö, 137 fractures of the distal third of the femur, 56 and 81 respectively, had been treated from 1969 through 1976 and reviewed with regard to age, sex, previous disease, type of fracture, treatment and results in another study (Kolmert and Wulff).⁹ In 1978 forty-four patients were dead, 22 did not reply to three enquiries and could not be traced. The pre- or postoperative radiograms had disappeared in five cases. Two patients were pregnant. During the period one patient was treated for two fractures of the same limb and one with prosthetic replacement of the knee. Thus 62 fractures (22 male and 40 female) comprised the material for this investigation. Thirty-five fractures had been treated non-surgically with traction and/or cast and 27 surgically. The average age on sustaining the fracture was 59 years (range 18-91) and at the follow-up 64. The mean observation time was five years and 1 month (range 13-117 months). Four patients were observed less for than two years. Thirty-one patients had previous disease and/or fractures of the injured limb.

In 30 patients the trauma (Alffram and Bauer 1962)³ was considered severe following traffic accidents (T) and falls from heights or in negotiating stairs (H) and in 31 as moderate, mainly after a fall at ground level (F). A fall from sitting position in a chair or from lying in bed was considered as moderate, while a fall from standing on a chair or a table was severe.³ Previous diseases, age over 50 and the degree of trauma are illustrated in the Venn diagram in Fig 1.

Previous diseases

Age over 50



Violent trauma

Fig 1. Relation of current diseases and previous fractures, age over 50 and violent trauma in 62 distal femoral fractures.

Radiographic examination

The pre- and postoperative examinations were obtained by two perpendicular projections.

The follow-up examinations were obtained as follows:

1. Standing antero-posterior (A-P) films of both knees stressed in valgus and varus (Fig 2) for femoro-tibial arthrosis (Ahlbäck 1971, Norman 1974).^{2,14}
2. Axial radiographs of both patellar joints in the standing position and a suitable degree of flexion (Fig 3) for patellar arthrosis (Ahlbäck 1971).²
3. Whole lower limb radiograms of both knees, with the patients standing on the examined limb only, using two X-ray tubes, with their central rays perpendicular to each other. The frontal plane was parallel to the tangent of the most posterior aspects of the femoral condyles which was ascertained by fluoroscopy in the lateral view. The subsequently obtained lateral radiograph included the knee and the distal two thirds of the femur (Edholm 1966, Maquet 1976).^{7,11}

Six of the 61 patients were unable to stand during the examination.

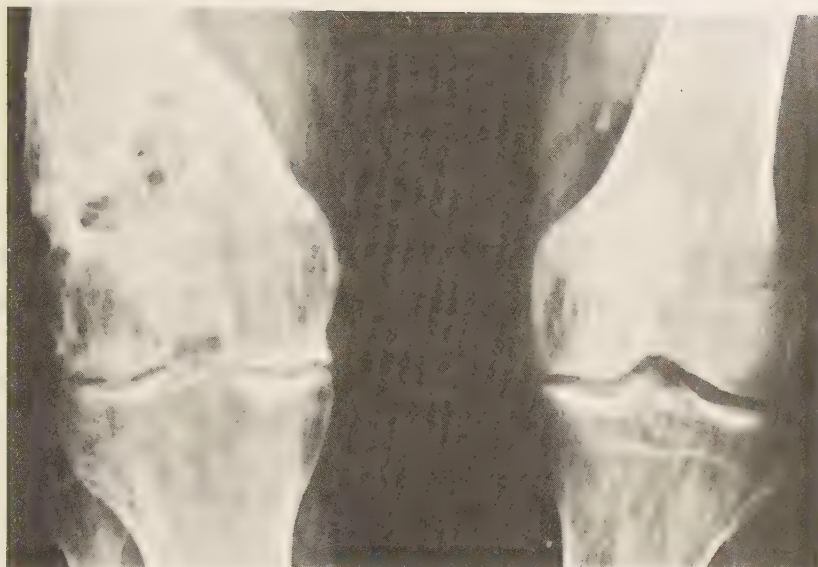


Fig 2. Standing radiographs of both knees stressed in valgus. Stage II medio-lateral gonarthrosis on the right side. Marked deformity of the supracondylar fracture. The HKA-angle was 192° (case B 32).

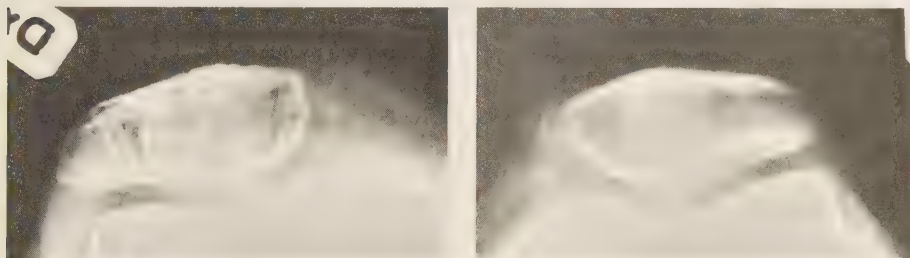


Fig 3. The axial projection of the patellar joint with an intra-articular fracture on the right side treated with a screw. There is still separation and difference in joint level in the lateral condyle after surgery. The patella is shifted laterally. Left side for comparison (case U 12).

Radiographic definitions and measurements

Displacement of the fragments were considered as translation along or rotations about three axes, perpendicular to each other: the longitudinal axis of the femoral diaphysis, the sagittal and the transverse axis. The supracondylar and intercondylar displacement of the fractures was measured as follows:

Supracondylar fractures (including the supracondylar part of the bicondylar fractures). Ad latus displacement was expressed as the proportion between bone contact area and cross sectional area. Thus no contact between proximal and distal fragment = 0 and complete contact = 1*.

Rotation about the sagittal axis of the fracture, valgus or varus deformity, was described as the lateral angle between the longitudinal axis of the proximal femur and a line joining the most distal points of the femoral condyles. This angle was compared to that of the unfractured femur as a reference. Rotation about the transverse axis was estimated using the shape of the condyles and the intercondylar fossa (Blumensaat's line) which was compared to the unfractured femur.

The total rotation (V) about the transverse as well as the sagittal axis of the fracture was calculated according to Bogdanov, 1950.^{4**}

Intercondylar fractures. The translation was expressed as distance between the fragments obtained in frontal, lateral and axial projections.

Translation along the longitudinal axis included shortening of the supracondylar fracture, which was measured in steps of 0.5 cm, and displacement in proximal direction of one condyle in comparison to the other, which was measured in mm (diastasis and difference in joint level).

$$\frac{\text{* Bone contact area}}{\text{Cross sectional area}} = \frac{2}{\pi} (\arccos G - G \sqrt{1 - G^2})$$

$G = \frac{h}{2r}$; where r is the radius and h is the true distance between longitudinal axes of the proximal and the distal fragments obtained by two perpendicular projections and their respective distances a and b. $h = \sqrt{a^2 + b^2}$.

** $\text{tg } V = (\text{tg}^2 a + \text{tg}^2 b)^{1/2}$, where a and b represents the angulation in the frontal and sagittal planes.

Rotation about the sagittal axis of the knee (valgus- or varus deformity) was related to the lateral angle between the lines joining the center of the femoral head, the tibial eminence and the center of the ankle joint - the Hip, Knee, Ankle - angle ($> 180^{\circ}$ = varus, $< 180^{\circ}$ = valgus). It is described as the HKA-angle in the following (Maquet 1976).¹¹

Arthrosis was measured radiographically in the standing position as defined and staged I-V (Ahlbäck in 1971)² depending on cartilage and bone destruction.

Clinical examination

At the follow-up the patients were assessed (Ranawat et al 1976)¹⁶ in the Knee Disability Sheet prepared at the Hospital for Special Surgery. Painfree with normal function gave a score of 100. Over 84 was excellent, 70-84 good, 60-69 fair and below 60 poor.

The clinical examination included range of motion in both knee joints for comparison and in both hip joints to assess concomitant hip disease influencing post-fracture function. Angular measurements were performed with a goniometer. The differences in length of the lower limbs were measured in the supine position from the anterior superior iliac spine to the medial malleolus.

The walking capacity was staged in three groups:

- A. Walking without external support
- B. Walking with one or two sticks or crutches
- C. Walking only with walking frame or assistance and non-walkers

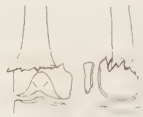
RESULTS

The 62 fractures were grouped according to the primary displacement, the fracture lines and relation to the femoral condyles and shaft (Table 1-3).

TABLE 1: SUPRACONDYLAR FEMORAL FRACTURES



a= No displacement



b= Supracondylar displacement



c= Supracondylar displacement + comminution

FRACTURE	PATIENT				TRAUMA				FOLLOW-UP							
Classification	N.o	(S....)	Age	Sex	Prev. disease	Degree	Contact area	Total angle	Operation	Obs-time year/month	Walk cap.	HSS points	Contact area	Total angle	Develop-ment of arthrosis	
														IT	P	
a. NO DISPLACEMENT	1	81	M	Amp	F	1.0	4	-		5/7	B	100	1.0	4	-	-
	2	70	F	—	F	1.0	4	-		3/4	B	61	1.0	3	-	-
	3	43	F	Po	F	1.0	5	-		3/3	C	100	1.0	7	-	-
b. SUPRACONDYLAR DISPLACEMENT	4	58	F	CV D	F	0.5	9	-		4/5	C	51	0.6	3	-	-
	5	56	M	HF	F	0.7	14	+		9/6	B	51	1.0	0	-	-
	6	57	F	GA	F	0.0	29	+		2/6	A	94	1.0	35	-	-
	7	57	M	—	H	1.0	32	+		6/0	A	98	1.0	2	-	-
c. SUPRACONDYLAR DISPLACEMENT + COMMUNION	8	65	F	MS	F	1.0	3	-		6/1	C	90	1.0	4	-	-
	9	62	F	RA	F	0.8	17	-		2/9	B	84	0.7	10	-	-
	10	52	M	TF	F	0.5	11	-		5/11	A	100	0.8	8	-	-
	11	64	F	Ep	T	0.6	20	-		4/6	C	100	0.6	26	-	ML 2
	12	70	F	—	T	0.2	13	+		1/5	B	89	0.4	15	-	-

Abbreviations: Sex: M = male; F = female

Previous diseases fractured leg

CA: Osteo-arthritis (coxarthrosis)
 GA: " " (gonarthrosis)
 FF: Femoral fracture
 HF: Hip fracture
 KF: Knee(eminence) fracture
 MF: Malleolar fracture
 TF: Tibial condylar fracture

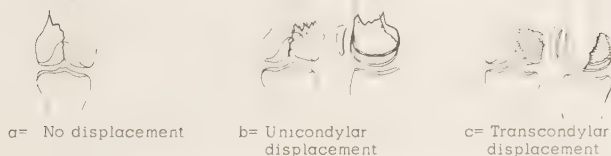
Amp: Below knee amputation
 CVD: Cerebro-vascular disease
 CD: Congenital deformity of leg
 Ep: Epilepsy
 MS: Sclerosis disseminata
 Par: Parkinson
 Po: Polio
 HSS: Hospital for Special Surgery

Trauma:
 F: Low-energetic
 H: High-energetic
 T: High-energetic from traffic

Arthrosis:
 FT: Femoro-tibial joint
 P: Patellar joint
 M: Medial
 L: Lateral
 ML: Medial + Lateral

Evaluation of the healed supracondylar femoral fractures (Table 1) showed that only 1/9 of the displaced fractures had arthrosis and that three had 15° or more of total angular deformity.

TABLE 2: UNICONDYLAR FEMORAL FRACTURES



FRACTURE	PATIENT				TRAUMA				FOLLOW - UP							
Classification	N.o (U....)	Age	Sex	Prev. disease	Degree	Condyle M/L	Total angle	Operation	Obs-time year/month	Walking cap.	HSS points	Total angle	Diast. IC † mm	Diff. joint level	Development of P	arthrosis
a. NO DISPLACEMENT	1	75	F	GA	F M	0	-		3/9	C	80	0	0	0	-	-
	2	69	F	KF	F M	2	-		2/11	B	89	0	0	0	-	-
	3	59	M	Po	F M	0	-		6/1	B	95	0	0	0	-	-
	4	61	M	-	F L	0	+		7/0	A	95	0	0	0	-	-
	5	64	F	-	F ML *	0	-		1/6	C	95	0	0	0	-	-
b. UNICONDYLAR DISPLACEMENT	6	70	F	-	F L	5	-		7/7	B	90	7	3	2	-	-
	7	75	F	KF	F L	0	+		9/10	B	100	0	10	0	-	-
	8	68	F	-	F L	1	-		5/1	A	91	5	4	2	-	-
	9	75	F	-	F L	3	+		4/1	A	91	5	3	4	-	MLI
	10	60	F	Ep	F L	11	+		3/6	A	93	5	5	8	-	LI
	11	75	M	Ep	F L	5	+		2/6	C	100	5	0	0	-	-
	12	71	F	-	T L	3	+		8/7	A	100	5	10	4	-	-
	13	63	F	GA	T L	14	-		7/6	A	98	15	11	11	-	-
c. TRANSCONDYLAR DISPLACEMENT	14	61	M	GA	H M	6	+		2/11	A	100	6	0	0	-	-
	15	25	M	-	H L	2	+		6/3	A	84	2	0	0	-	-

† IC = Intercondylar

* Intercondylar with unidentifiable proceeding

For other abbreviations see below Table 1.

Evaluation of the healed unicondylar femoral fractures (Table 2) showed that 2/10 of the displaced fractures had developed arthrosis in the patellar articulation and none in the femoro-tibial. One had 15° of total angular deformity and one had 10 mm difference in the joint level.

TABLE 3 a,b; BICONDYLAR FEMORAL FRACTURES



a= No displacement



b= Supracondylar displacement

FRACTURE	PATIENT				TRAUMA				FOLLOW - UP									
CLASSIFICATION	N.O (B....)	Age	Sex	Prev. disease	Degree	Contact area	Total angle	Operation	Obs-time year/month	Walking cap.	HSS points	Contact area	Total angle	Diast. IC, mm	Diff. joint level	Development of arthrosis	FT	P
a. NO DISPLACEMENT	1	61	F	-	F	1.0	5	-	7/9	A	95	1.0	6	0	0	-	-	
	2	59	F	CVD	F	1.0	1	-	3/10	A	90	1.0	1	0	0	-	-	
	3	77	F	HF	F	1.0	2	-	7/4	A	100	1.0	0	0	0	-	-	
	4	50	F	-	H	1.0	0	+	8/7	A	83	1.0	6	2	2	-	-	
	5	59	F	-	T	1.0	3	-	7/11	A	100	1.0	3	2	2	-	-	
	6	71	M	-	T	1.0	5	+	7/1	B	75	1.0	0	0	0	L2	L1	
b. SUPRACONDYLAR DISPLACEMENT	7	91	M	-	F	0.6	5	-	4/5	B	85	0.6	3	4	3	-	-	
	8	92	F	FF	F	0.6	20	-	2/0	C	90	0.4	20	0	0	-	-	
	9	91	F	HF	F	0.2	12	-	3/6	A	72	0.4	16	0	0	-	-	
	10	74	F	-	F	0.3	4	-	9/9	C	100	0.5	16	0	0	-	-	
	11	71	F	GA	F	0.4	27	-	4/10	B	72	0.6	7	0	0	-	-	
	12	74	F	Par	F	0.2	35	+	5/4	B	100	0.8	14	0	0	-	-	
	13	68	F	CA	H	0.6	30	-	4/10	B	82	0.6	20	0	3	-	-	
	14	72	F	-	H	0.0	8	+	2/6	B	92	1.0	8	2	1	-	-	
	15	67	F	MF	H	0.0	21	+	2/9	B	87	0.4	25	0	0	-	-	
	16	63	M	-	T	0.4	8	-	3/3	A	55	0.4	17	0	0	-	-	
	17	18	M	PD	T	0.6	16	+	8/4	A	90	1.0	9	0	0	-	-	

For abbreviations see below Table 1.

Evaluation of the healed bicondylar femoral fractures (Table 3) showed 1/17 of the undisplaced fractures with arthrosis compared to 10/18 among those with intercondylar diastasis.

TABLE 3 c, d: BICONDYLAR FEMORAL FRACTURES



c = Supra- and intercondylar displacement

d = Transcondylar displacement

FRACTURE	PATIENT				TRAUMA				FOLLOW - UP									
CLASSIFICATION	N.o (B.....)				Degree	Contact area	Total angle	Operation	Obs-time year/month	Walking cap.	HSS points	Contact area	Total angle	Diaet. IC. mm	Diff. joint level	Development of arthrosis		
	Age	Sex	Prev. disease													I	T	P
c. SUPRA- AND INTERCONDYLAR DISPLACEMENT	18	65	F	CD	F	0.0	20	-	1/1	C	57	1.0	19	5	4	-	-	-
	19	70	F	GA	F	0.8	10	+	1/6	B	100	0.8	12	5	0	-	-	-
	20	23	M	-	H	0.6	26	+	4/0	A	100	1.0	3	5	0	-	-	-
	21	54	M	-	T	0.3	21	-	5/0	B	62	0.2	22	10	10	-	-	MI
	22	51	M	-	T	0.5	6	-	4/2	A	95	0.5	31	10	0	-	-	-
	23	57	F	-	T	1.0	15	-	6/11	B	91	1.0	15	6	3	-	-	LI
	24	57	F	-	T	0.0	24	-	6/11	B	91	1.0	15	5	4	-	-	-
	25	22	M	-	T	1.0	6	-	6/11	A	100	1.0	6	5	5	-	-	LI
	26	39	F	-	T	0.6	7	-	5/0	A	94	0.6	12	7	5	-	-	ML2
	27	58	F	HF	T	1.0	12	-	8/4	A	99	1.0	10	5	0	-	-	MLI
	28	75	F	-	T	1.0	18	-	3/11	B	36	1.0	35	8	5	-	-	-
	29	46	F	-	T	1.0	3	-	8/9	A	91	1.0	7	6	4	-	-	-
	30	50	M	PF	T	0.7	30	-	3/7	B	75	0.7	30	5	5	MLI	MLI	MLI
	31	24	F	-	T	0.0	12	+	5/2	A	93	0.2	1	7	5	-	-	L2
d. SUPRA-, INTER- AND TRANS-CONDYLAR DISPLACEMENT	32	59	M	-	H	0.2	36	+	6/6	B	49	0.5	15	4	4	ML2	MLI	MLI
	33	45	M	Po	T	0.4	17	-	7/0	B	44	0.4	19	10	0	-	-	ML2
	34	40	M	-	T	0.5	5	-	2/2	A	22	0.9	22	5	0	-	-	MIL2
	35	26	M	-	T	0.3	8	+	5/2	A	88	1.0	1	0	0	-	-	-

For abbreviations see below Table 1.



Fig 4. Distribution of varus/valgus angular deformities in the healed unicondylar fractures.

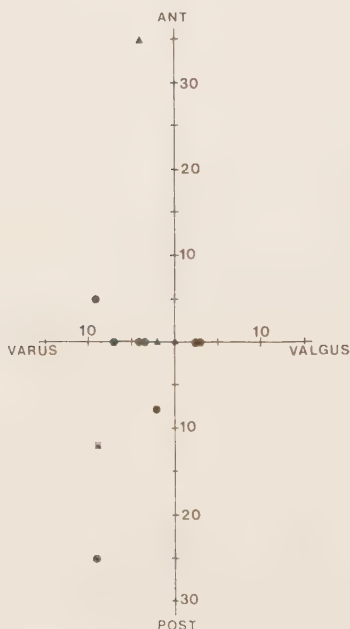


Fig 5.

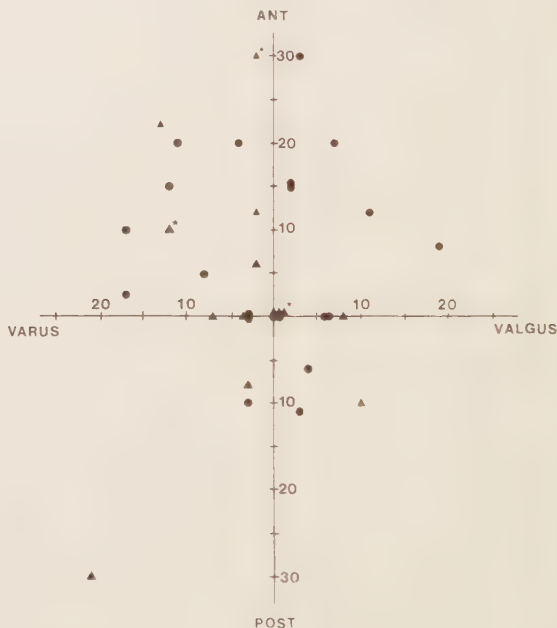


Fig 6.

Fig 5. Distribution of varus/valgus and antero-posterior angular deformities in the healed supracondylar fractures.

Fig 6. Distribution of varus/valgus and antero-posterior angular deformities in the healed bicondylar fractures.

In the healed unicondylar fractures (Fig 4), the medial fractures displaced into varus and the lateral into valgus. In the supracondylar fractures (Fig 5) the most common deformity was varus and the bicondylar fractures (Fig 6) showed varus and anterior angulation.

There was no marked difference in reduction of the displacement on primary films after conservative or operative treatment with regard to total angle for all groups. This was true both for the total angle and if the displacement in antero-posterior and lateral direction was considered separately. The bone contact area however was improved following both surgical and non-surgical treatment.

For 21 unfractured knees without arthrosis the correlation quotient between the mean HKA and the mean lateral angle was 0.64 and for the fractured side 0.87.

Three patients developed femoro-tibial as well as patellar arthrosis and another eleven patients developed patellar arthrosis only. Excluding those with arthrosis at trauma, the patients with arthrosis in the other knee at follow-up and those observed less than two years, 3/51 developed femoro-tibial and 14/51 patellar arthrosis. All three with femoro-tibial and seven of those with patellar arthrosis complained of discomfort in the knee (10/14) and four did not (4/14).

Arthrosis of the femoro-tibial articulation in the three patients with bicondylar fractures, varied between stage I and II. Case B30 had an anterior angulation of 30° . Case B32 (Fig 2) had a varus deformity of 12° and a total deviation of 15° as well as a lateral transcondylar fracture (Fig 7). Both case B30 and B6 had subchondral fractures but no varus or valgus deformity. Despite severe angular deformities no additional patients developed femoro-tibial arthrosis.

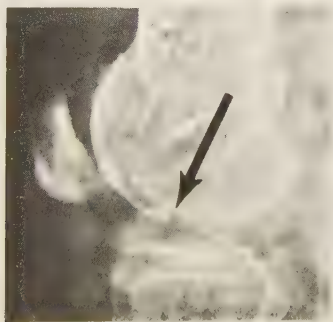


Fig 7. Bicondylar fracture combined with transcondylar (in plaster). The arrow indicates the planar difference caused by the transcondylar fracture (case B32)

Gonarthrosis in the patellar joint varied between stage I and II (e.g. Fig 8). In case S 11 the patellar joint of the supracondylar fracture was distorted by distal displacement of the femoral shaft (Fig 9).

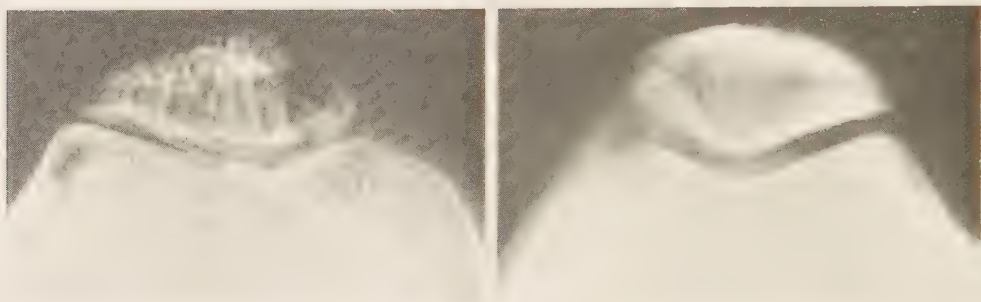


Fig 8. Left patellar joint with gonarthrosis of stage II. Callus formation is seen at the fracture site (case B 26).

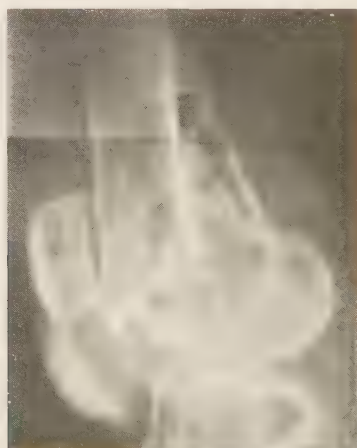


Fig 9. Healed supracondylar fracture with engagement of the patellar joint (case S 11).

Three of the eleven patients with solely patellar arthrosis showed scores of 62, 44 and 22. These three also had the most pronounced total angular deviation, intercondylar diastasis and difference in joint level of the patients with arthrosis. However, there are also high values in patients without developed arthrosis within the observed period.

The two transcondylar, unicondylar fractures were stabilized surgically in an exact position. These knees did not develop arthrosis. Two patients without arthrosis in the bicondylar group had intercondylar diastasis and scores below 60. The HSS score showed an average of 91, 77, 85 and 51 for the bicondylar groups (a-d).

The relationship of intercondylar diastasis and difference of level in the joint surface to arthrosis (Table 4) showed statistically significant values* when the values exceeded 3 mm in the intraarticular fractures. The influence on arthrosis of contact area and total angulation in the supracondylar and bicondylar fractures was not significant.

Table 4. Number of patients with gonarthrosis in proportion to number of patients with different types of fractures and fracture displacement.

Type of fracture	Diastasis, mm		Diff joint level, mm	
	0 - 3	Above 3	0 - 3	Above 3
Unicondylar fractures	1/10	1/5	0/11	2/4
Bicondylar fractures	1/17	10/18	5/25	6/10

DISCUSSION

The ideal reference in assessing results of management of fractures of the leg is the pre-fracture condition for the individual patient. As this is rarely known, comparison with the other knee, previous fractures and current diseases were made in this study, thus a parietic or bedridden patient with contractures was not expected to gain a full range of motion, but should on the other hand be pain-free following treatment for the fracture and if so was given the maximal score.

* Statistical analysis by Chi-square test with Yate's correction ($0.001 < p < 0.01$).

Laros (1979)¹⁰ discussed and compared ten recent reports of distal femoral fractures and found a great variety of opinions regarding assessment of results. Based on this, he stressed the prognostic importance of comminution, articular damage, ipsilateral fractures, soft tissue damage and osteoporosis. Our classification depends on displacement, comminution and articular damage. Only one ipsilateral and four open fractures were seen. Osteoporosis, estimated on the radiographic films at the time of trauma, did not show any influence on the final outcome in this material.

Schatzker and Lambert (1979)¹⁹ stated that, "the type of trauma had little bearing on the quality of the result". They found most failures in ages above 50; 9/19, compared to 1/17 below 50, in patients treated with rigid internal fixation. They concluded that the use of this technique for the elderly, osteoporotic patient was "clearly beyond the surgeon's ability" and added that much attention must be paid to the importance of accurate reduction in preventing rapid development of arthrosis. Chiron et al (1973)⁵ found the intra-articular fracture to give poorer results than the simple or comminuted extra-articular fracture. This is confirmed in our material which showed a significantly higher incidence of arthrosis when differences in the joint level and diastasis between the condyles exceeded 3 mm. These authors, however, did not pay attention to the patellar joint. No reports had comparable radiographic measurements concerning angles, contact between fragments, difference in joint level and diastasis (Chiron et al 1974, Della Torre et al 1980, Modlin 1945, Neer et al 1967, Schatzker et al 1974, Stewart et al 1966).^{5,6,12,13,18-20}

Varus/valgus deformity of distal femoral fractures can either be described as displacement of fragments compared to the unfractured side or as deformities of the knee related to normal values of the femoro-tibial angle. The HKA-angle is a valuable expression of the biomechanical forces at the knee joint in valgus or varus deformities (Johnsson 1980, Maquet 1976).^{8,11} However, it often fails to

describe deformities of the fracture due to anatomical variations of the femur, rotations around its longitudinal axis and translatory displacements. The angle between the distal condylar plane and the anatomical axis of the proximal femur was preferred for assessment of displacement in valgus/varus of the fracture - if compared to the unfractured side. In most cases, however, the HKA-angle reflected the valgus/varus deformity at the fracture site but only in comparison to the "normal" side.

The deformities were described at the follow-up examination using defined radiographic projections (Edholm 1966).⁷ For the pre- and postoperative radiograms, obtained without exact definition, a rough estimation was made of the total angular deviation.

In previous reports the patellar joint was only considered on the antero-posterior and lateral projections. The axial radiogram contributed to the selection of intra-articular fractures from the supracondylar with unaffected joint surfaces. The distinction between displaced and undisplaced fractures including the patellar articulation also improved the classification.

The length of time for development of arthrosis is unknown and differs probably between those with only angular deviation in an extra-articular fracture and those with incongruence after an intra-articular. In the 204 tibial condylar fractures, re-examined by Rasmussen (1971),¹⁷ angular deviations more than 10° and instability showed a significant correlation to gonarthrosis. Those developing arthrosis usually experienced symptoms at the knee joint from the start and did not have a "free interval" as a rule. Influence on arthrosis from angular deviation in distal femoral fractures was not confirmed in this material but the observation time (2-10 years) is probably too short to exclude late gonarthrosis. Tjörnstrand 1981²¹ in his thesis on high tibial osteotomy for gonarthrosis found ten tibial condylar, four tibial shaft, one femoral shaft and one supracondylar femoral fracture in 212 consecutive patients.

For the tibial shaft fractures, 15-44 years had elapsed to when a corrective osteotomy was performed for the secondary arthrosis and for the femoral shaft and supracondylar fractures 20 and 15 years respectively. Eight tibial condylar fractures on the other hand were osteotomized 0-3 years after fracture.

The patients with displaced bicondylar fractures (Table 3, c+d) and arthrosis had been observed equally as long as those in the same group without arthrosis, if the patients observed less than 2 years were excluded; the age and walking capacity were comparable. The patients with arthrosis were all below 60 years having sustained violent trauma. Those with transcondylar fractures showed the poorest results in the final function according to the HSS assessment (Ranawat et al 1976).¹⁶ This sheet is formulated for assessing knee disability before and after surgery for rheumatoid arthritis and osteoarthritis and favours the range of motion, which though important after a fracture, is of limited value. This probably depends on both the small number of fractures in most of our groups and the differences in the background of the patients with frequent current diseases and previous fractures.

The findings in this material underline the importance of careful radiographic examination of the patellar compartment. This is obtained by the axial projection (or by computerized tomography, Fig 10) of the knee joint which will improve the classification and contribute to the treatment and final outcome.

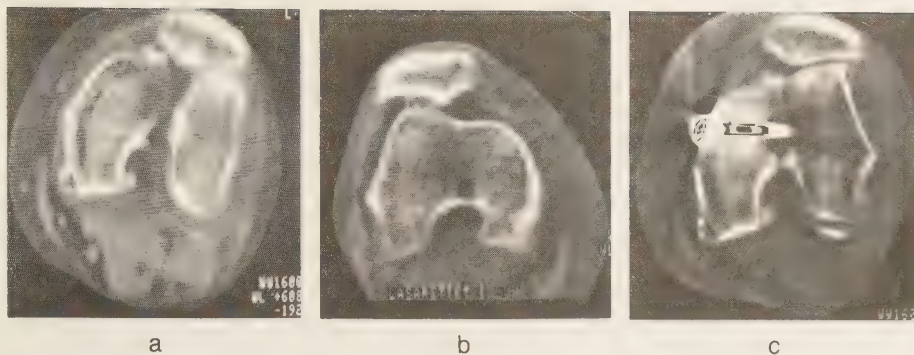


Fig 10. Computerized tomography with slice thickness 6 mm of the femoral condyles and the patella about 2.5 cm above knee joint level in an intra-articular, condylar fracture

- a) The fracture through the patellar joint and the intracondylar fossa with diastasis and difference in joint level
- b) Right side for comparison
- c) After surgery with screw fixation. The displacement is decreased

CONCLUSIONS

1. An anatomical classification into supracondylar, unicondylar and bicondylar fractures is proposed with subdivisions because of supracondylar, intercondylar and transcondylar displacement.
2. The most common deformity after bicondylar fracture was varus- and anterior angulation. Unicondylar medial fracture caused varus and lateral caused valgus deformity.
3. The patellar joint should be examined radiographically with axial projections on admission. Additional information is obtained as well by computerized tomography.
4. Early gonarthrosis developed mostly after bicondylar fractures with displacement both in the supracondylar and intercondylar regions, especially if transcondylar engagement occurred and a diastasis or planar difference in the articular surfaces was more than 3 mm.

ACKNOWLEDGEMENT

The statistical analysis was done by Karl Göran Thorngren, M.D., Department of Orthopaedic Surgery, University Hospital, Lund.

REFERENCES

1. Adams, J.C.: Outline of fractures. E & S Livingstone, London 1968.
2. Ahlbäck, S.-O.: Osteoarthritis of the knee. A radiographic investigation. Thesis Stockholm. Acta Radiologica Suppl 277, 1971.
3. Alffram, P.-A., Bauer, G.C.H.: Epidemiology of fractures of the forearm. J Bone Jt Surg 44-A: 105-114, 1962.
4. Bogdanov, G.: A method of determining the true angle of deviation in a fracture. Brit J Radiology 23:497, 1950.
5. Chiron, H.S., Trémoulet, J., Casey, P. and Müller, M.: Fractures of the distal third of the femur treated by internal fixation. Clin Orthop 100: 160-170, 1974.
6. Della Torre, P., Aglietti, P. and Altissimi, M.: Results of rigid fixation in 54 supracondylar fractures of the femur. Arch Orthop Traumat Surg 97: 177-183, 1980.
7. Edholm, P.: Anatomic angles determined from two radiographic projections. Thesis, Stockholm. Acta Radiologica Suppl N:o 259, 1966.
8. Johnsson, F., Leitl, S. and Waugh, W.: The distribution of load across the knee. J Bone Jt Surg 62 B: 346-349, 1980.
9. Kolmert, L. and Wulff, K.: Epidemiology and treatment of distal femoral fractures in adults. Acta Orthop Scand. Accepted for publication.
10. Laros, G.S.: Supracondylar fractures of the femur. Editorial comment and comparative results. Clin Orthop 138: 9-12, 1979.

11. Maquet, P.: Biomechanics of the knee with application to the pathogenesis and the surgical treatment of osteoarthritis. Springer Verlag, Berlin 1976.
12. Modlin, J.: Double skeletal traction in battle fractures of the lower femur. Bull U.S. Army Med Dept 119-120, 1945.
13. Neer, L.S. II, Grantham, S.A. and Shelton, M.L.: Supracondylar fractures of the adult femur. J Bone Jt Surg 49-A: 591-613, 1967.
14. Norman, O., in Hagstedt, B.: High tibial osteotomy for gonarthrosis. Thesis, Lund 1974.
15. De Palma: The management of fractures and dislocations. Saunders 1970.
16. Ranawat, C.S., Insall, J. and Shine, J.: Duo condylar knee arthroplasty. Clin Orthop 120: 76-82, 1976.
17. Rasmussen, P.: A functional approach to evaluation and treatment of tibial condylar fractures. Thesis, Gothenburg, 1971.
18. Schatzker, J., Horne, G. and Waddel, J.: The Toronto experience with supracondylar fracture of the femur. Injury 6: 113-128, 1974.
19. Schatzker, J. and Lambert, D.C.: Supracondylar fractures of the femur. Clin Orthop 138: 77-83, 1979.
20. Stewart, M.J., Sisk, T.D. and Wallace, S.L.: Fractures of the distal third of the femur: A comparison of methods and treatment. J Bone Jt Surg 48-A:784-807, 1966.
21. Tjörnstrand, B.: High tibial osteotomy for medial gonarthrosis. Thesis, Lund 1981. Personal communication.
22. Trentz, O., Tscherne, H. and Oestern, H.-J.: Operationstechnik und Ergebnisse bei distalen Femur Frakturen. Unfallheilkunde 80: 441-448, 1977.

AN EXPERIMENTAL STUDY OF DEVICES FOR INTERNAL
FIXATION OF DISTAL FEMORAL FRACTURES

by

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INTRODUCTION

Four per cent of all femoral fractures involve the distal third, and the majority of these fractures are caused by moderate trauma after the age of 50.⁸ Treatment in traction is not well tolerated by the aged, and plaster fixation may cause stiffness of the knee. However, old age, previous fractures and neurologic disease have often caused severe bone fragility which makes internal fixation difficult; the results of internal fixation of the distal femoral fracture are generally worse in the aged than in the young.^{1,8,10,11,13,14}

In an attempt to define the mechanical limitations of internal fixation devices used in the treatment of distal femoral fractures five different devices were tested under standardized experimental conditions. In clinical practice the unicondylar fracture usually gives satisfactory results.⁸ The condylar component in the bicondylar fracture is relatively seldom displaced. Therefore transverse supracondylar osteotomies 6 cm above the femoro-tibial joint level were made in cadaver femurs used for the experiment.

MATERIAL AND METHODS

Two devices often used in the treatment of the distal femoral fracture, the AO condylar angle plate^{1,2,8,9} and the Rush pin,^{8,11} were compared to the more recently developed Zickel supracondylar nail.¹⁵ The latter was then compared to a semi-elastic fixation device,⁵ the ECS (two Ender nails Coupled to cancellous Screws); developed and used at the Department of Orthopaedic Surgery in Lund since 1978. The ECS device was also tested against plain Ender nails. These devices represented one onlay type (the angle plate) and four intra-medullary types (Fig 1).

SPECIMENS AND PREPARATION

Sixteen paired specimens were used. To minimize the influence of inter-individual variation, different types of internal fixation

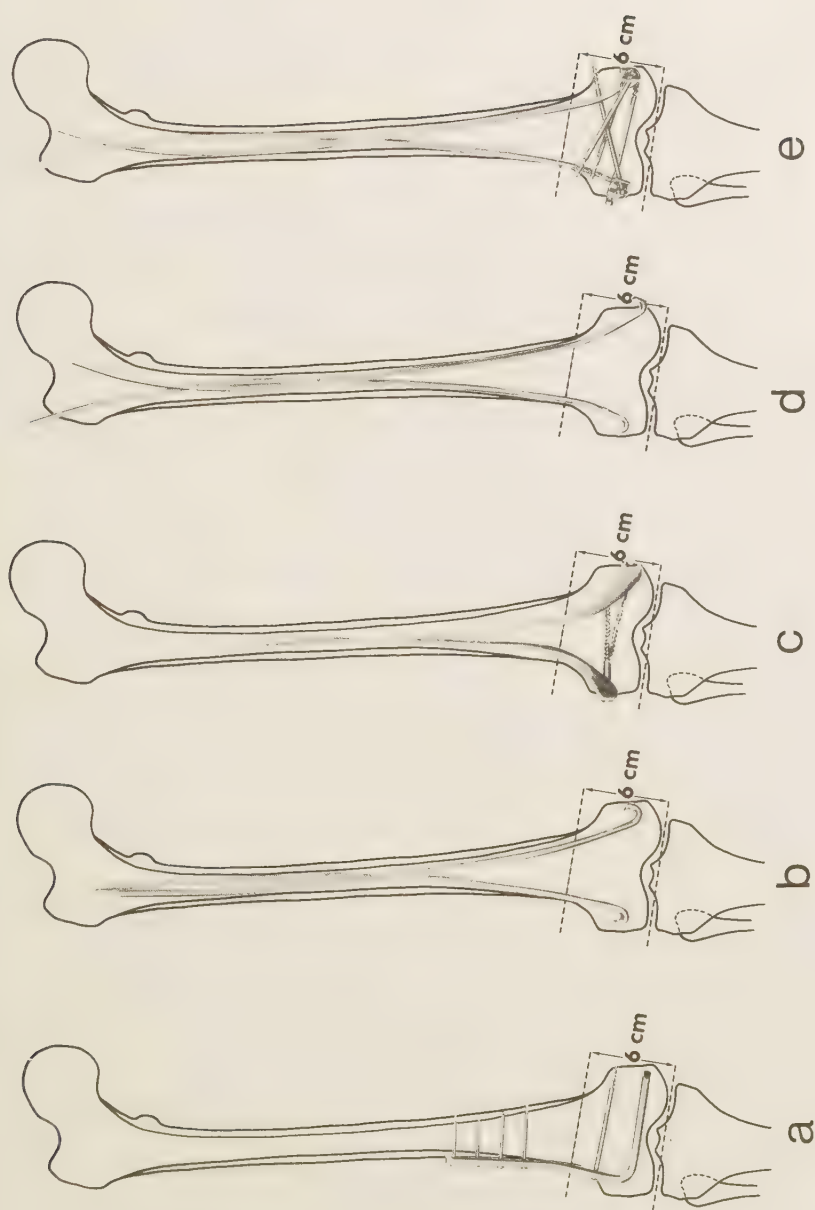


Fig 1. Fixation devices: a) AO condylar plate, b) Rush pins, c) Zickel supracondylar nails, d) plain Enders nails and e) ECS semi-elastic fixation.

Table 1. Specimen data in experimental fixation of the distal femur.

Specimens				Type of osteosynthesis	
Case no	Sex	Age	Cause of death	Right femur	Left femur
1	M	72	Myocardial infarction	Zickel	Rush
2*	F	63	Carcinoma of the bile ducts	"	"
3	F	72	Carcinoma of the lung	"	"
4	M	68	Cerebral bleeding	"	"
5	M	76	Carcinoma of the lung	Zickel	AO plate
6	M	69	Aneurysm of the aorta	"	"
7	F	77	Myocardial infarction	"	"
8**	F	60	Carcinoma of the pancreas	" + cement	"
9***	F	81	Carcinoma of the bile ducts	Zickel	ECS
10***	M	70	Carcinoma of the bile ducts	"	"
11***	M	77	Carcinoma of the rectum	ECS	Zickel
12	M	77	Carcinoma of the lung	Zickel	ECS
13	F	81	Carcinoma of the stomach	"	"
14	F	96	Emboli of the lung	"	"
15	F	80	Carcinoma of the lung	ECS	Ender
16	M	61	Carcinoma of the stomach	"	"
17	F	78	Myocardial infarction	Ender	ECS

Fixation devices:

Zickel = 2 Zickel supracondylar nails with screws

Rush = 2 Rush pins

AO = AO condylar plate + 1 cancellous screw + 4 cortical screws

Ender = 2 Ender nails

ECS = 2 Ender nails each coupled to two cancellous screws traversing both condyles

* = Preparation failed

** = Set up failed

*** = Femur sectioned below the lesser trochanter

were performed on the right and left sides in each individual (Table 1). None had sustained a fracture of the lower extremities. The age range (60-96 years) was chosen so as to obtain specimens with some old age fragility. The specimens included 14 pairs of full length femurs and 3 pairs where the femur was sectioned below the lesser trochanter. The tibia and fibula were sectioned 15 cm below the knee joint. The specimens were cleansed of soft tissues including the patella while all other ligaments and the fibrous capsule around the knee joint were preserved. Different fixation devices were used in each pair which then were kept frozen at -20°C and allowed to thaw at room temperature 12-24 hours before testing. Two pairs (n:o 2 and 8) were excluded, the first because of failure in preparation on one side, the second because of limitations of the holding device when rotation was tested.

INTERNAL FIXATION DEVICES

AO condylar angle plate⁹ (Synthes AB, Sweden)

A 95° angled blade plate with 7.5 cm blade and 7 holes for cortical and 2 for cancellous screws were used. It was applied along the lateral side and fixation of the condylar part was supplemented with one cancellous screw through the plate. Compression was applied and the proximal 4 holes were used for cortical screws, securing the plate to the femoral shaft.

Rush pins¹¹ (Stille-Werner AB, Sweden)

Two 38.5 cm long, 6 mm thick pins, were inserted one from each condyle 1.5 cm proximal to the joint, between the anterior border of the joint and the femoral insertion of the collateral ligaments.

Zickel supracondylar device¹⁵ (Howmedica Inc., Sweden)

Two Zickel nails 28 cm long and 5 mm in breadth at the top were used. An opening was made for each, 1.5 cm above the joint between the anterior border of the joint and the femoral insertion of the

collateral ligaments. A 7.5 cm long cancellous screw, was applied through each nail, penetrating the cortex of the opposite condyle.

Ender nails (Gibeck AB, Sweden)

Two Ender nails 40-45 cm long, 4.5 mm thick, were inserted from each condyle, 1.5 cm above the knee joint between the anterior border of the joint and the femoral insertion of the collateral ligaments. The tip of the lateral one was passed through the greater trochanter and that of the medial nail into the femoral neck. In three specimens divided below the lesser trochanter, the nails extruded through the proximal end of the cut surface.

ECS (Ender nails Coupled to cancellous Screws)^{5,6,7} (Gibeck AB and Stille-Werner AB, Sweden).

After two Ender nails had been inserted as described above a coupling piece and two cancellous screws were added to each nail; the screws penetrated the opposite cortex.

Experimental set up

Each femoral shaft was fixed horizontally in a specially constructed holding device (Fig 2). Force was transmitted to the specimen through a steel wire loop around the tibia. The distances between the holding device, osteotomy and wire loop were constant. The initial deflexion of the osteotomies and the knee joints was assessed prior to each test by measuring the angle between the femoral shaft and the proximal tibia. The specimens were tested in a standard material testing machine, Alwetron Model T/2000. The deformation rate was 50 mm/min corresponding to an angular deformation of 16° /min. The load and the time were registered on a XY-recorder (Fig 3).^{3,4}

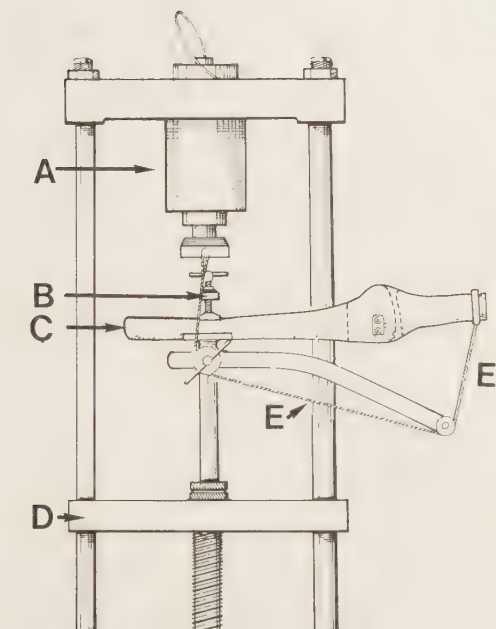


Fig 2. Experimental set up: A = load cell. B = holding device. C = specimen in extension. D = moving cross head. E = wire.



Fig 3. Load-deflexion curve. Diagram from pair n:o 6, AO-condylar plate, first test in extension. Y = load (Newton), X = deflexion in degrees.

TESTING

The displacement of fractures at the distal third of the femur occur mainly in the sagittal and frontal planes.^{10,13,14} Thus, testing was performed in forced extension, followed by abduction. To evaluate the residual stability after these initial tests a third test in extension was performed; the position and stability of the fractured ends were usually maintained after the initial tests. All tests were continued until failure or to 40° of deflexion.

CALCULATIONS

The maximal bending moment at the osteotomy was calculated as the maximal load at failure or at 40° deflexion (Fig 3). Flexibility was calculated from the linear part of the load deformation curve. Thus, the load at 30 mm or about 10° of linear deflexion was used as a measure of flexibility in the osteosynthesized specimens.

$$\text{Flexibility} = \frac{\text{deflexion (30mm} = 9.6^\circ\text{)}}{\text{bending moment}} \quad (\text{degrees/Newton meter})$$

RESULTS

CHARACTERISTICS IN PAIRED TESTING

Zickel versus Rush (Table 2)

In extension the Zickel device resisted heavier loads than the Rush pins. A small fracture occurring in the tibial condyle in the first Zickel test was of no importance for the second and third tests. Even in the Rush pin fixation small fractures occurred in the first pair when the head of the pin cut through the condyles. The fixation of the Zickel nail was more secure in the distal fragment due to the cross compression screw. A similar difference was seen when abduction was performed. The Zickel specimens were also less flexible in extension while this was not noticed in abduction. The residual stability (third extension) was sound enough to permit a second hyperextension with approximately the same results in moment for all three pairs with both the Zickel and Rush pins.

Table 2. Maximal bending moment at the osteotomy site and flexibility in bending tests of paired distal femoral specimens.

Zickel versus Rush

Test direction	Type	Moment at osteotomy (Nm)			Flexibility ($^{\circ}$ /Nm)		
		Pair no 1	3	4	Pair no 1	3	4
1. Extension	Zickel	54	63	49	0.43	0.61	0.70
	Rush	18	40	40	1.11	1.03	1.33
	Difference	36	23	9	-0.68	-0.42	-0.63
2. Abduction	Zickel	54	72	47	0.67	0.51	0.78
	Rush	29	50	36	0.44	0.67	0.70
	Difference	25	22	11	0.23	-0.16	0.08
3. Extension	Zickel	59	58	38	0.46	0.43	0.56
	Rush	25	32	32	0.78	1.03	0.64

Zickel versus AO (Table 3)

In extension pair number 7 showed much better resistance to load for the AO condylar plate while there was no major difference in pairs 5 and 6. Fractures were seen in the first test in extension in all pairs. In the osteotomies stabilized by the Zickel device the fracture appeared in the anterior distal part of the proximal shaft. Bone stabilized by the AO condylar plate showed fractures through the screw holes in the proximal shaft and in pair number 7 the bone was split into two halves which excluded further testing. In abduction, the AO condylar plate in pairs 5 and 6 resisted increased loading compared to the Zickel. However, when loaded in abduction the condylar plate was bent at the site of the osteotomy leading to distraction of the bone ends. Flexibility was less for the AO condylar plate than for the Zickel fixation. The residual stability could be tested only in pair number 6.

Table 3. Maximal bending moment at the osteotomy site and flexibility in bending tests of paired distal femoral specimens.

Zickel versus AO

Test direction Type		Moment at osteotomy (Nm)			Flexibility ($^{\circ}$ /Nm)		
		Pair no			Pair no		
		5	6	7	5	6	7
1. Extension	Zickel	58	81	72	0.61	0.38	0.51
	AO	61	72	133	0.39	0.26	0.18
	Difference	-3	9	-61	0.22	0.12	0.33
2. Abduction	Zickel	56	47	67	0.42	0.58	0.37
	AO	72	90	-	0.33	0.25	-
	Difference	-16	-43	-	0.09	0.33	-
3. Extension	Zickel	-	47	-	-	0.70	-
	AO	-	50	-	-	0.38	-

Zickel versus ECS (Table 4 and 5)

In this series (Table 4) the specimens were sectioned below the lesser trochanter and there was therefore no proximal stabilization. In extension in pairs number 10 and 11 the Zickel device resisted an increased load. In abduction the results were similar. Fractures were seen only in pair number 9 where the fracture might explain the inverse difference in abduction. Flexibility was greater in the ECS device. Residual stability was good in 2 experiments with the Zickel device and in all three with the ECS devices.

Table 4. Maximal bending moment at the osteotomy site and flexibility in bending tests of paired distal femoral specimens.

Zickel versus ECS. Femur sectioned below the lesser trochanter.

Test direction	Type	Moment at osteotomy (Nm)			Flexibility ($^{\circ}$ /Nm)		
		Pair no			Pair no		
		9	10	11	9	10	11
1. Extension	Zickel	40	94	117	0.74	0.37	0.36
	ECS	34	45	50	0.89	0.49	1.03
	Difference	6	49	67	-0.15	-0.12	-0.67
2. Abduction	Zickel	13	79	83	0.89	0.42	0.31
	ECS	38	43	38	0.95	0.70	0.95
	Difference	-25	36	45	-0.06	-0.28	-0.64
3. Extension	Zickel	-	76	72	-	0.48	0.35
	ECS	29	40	38	1.03	0.67	0.70

ECS fixation in whole femora (Table 5) increased the proximal anchorage compared to Zickel fixation. In extension it resisted the same or heavier load compared to the Zickel. In abduction there was practically no difference except in specimen 13 where a fracture in the proximal femur excluded testing of the ECS. Fractures of less importance were seen when the Zickel was tested in extension in the first two pairs and the ECS in the last pair. The fractures appeared in the anterior distal part of the proximal shaft. The flexibility was greater for the ECS in pairs number 13 and 14 in extension, while in pair number 12, the Zickel was more flexible. Residual stability was shown in two ECS preparations and only in one Zickel.

Table 5. Maximal bending moment at the osteotomy site and flexibility in bending tests of paired distal femoral specimens.

Zickel versus ECS. Intact femurs.

Test direction	Type	Moment at osteotomy (Nm)			Flexibility ($^{\circ}$ /Nm)		
		Pair no			Pair no		
		12	13	14	12	13	14
1. Extension	Zickel	43	25	23	0.70	0.58	1.03
	ECS	54	40	25	0.49	0.74	1.48
	Difference	-11	-15	-2	0.21	-0.16	-0.45
2. Abduction	Zickel	50	18	23	0.48	0.58	0.89
	ECS	50	0	18	0.64	0.33	1.21
	Difference	0	18	5	-0.16	0.25	-0.32
3. Extension	Zickel	-	-	22	-	-	0.68
	ECS	50	-	16	0.83	-	1.90

ECS versus Ender (Table 6)

These tests were performed to compare the differences between intramedullary nails with a distal coupling and plain intramedullary nails. In extension the ECS device resisted increased load. In abduction there was a similar difference. Flexibility was greater where the plain intramedullary nails had been used due to cutting through at the insertion in the condyles, similar to Rush pin fixation. Residual stability was more pronounced for the ECS. No fracture of importance was seen.

Table 6. Maximal bending moment at the osteotomy site and flexibility in bending tests of paired distal femoral specimens.

ECS versus Ender

Test direction	Type	Moment at osteotomy (Nm)			Flexibility ($^{\circ}$ /Nm)		
		Pair no			Pair no		
		15	16	17	15	16	17
1. Extension	ECS	49	59	52	0.64	0.67	0.67
	Ender	34	47	27	0.89	0.67	1.03
	Difference	15	12	25	-0.25	0	-0.36
2. Abduction	ECS	50	52	50	0.53	0.43	0.61
	Ender	40	40	34	0.89	0.49	0.95
	Difference	10	12	16	-0.36	-0.06	-0.34
3. Extension	ECS	45	50	41	0.95	0.44	0.83
	Ender	29	38	25	1.11	1.48	1.21

CHARACTERISTICS OF EACH INDIVIDUAL TYPE OF INTERNAL FIXATION

Zickel

The Zickel nail seemed to ensure reliable distal fixation because of the configuration of the nails and the screws through the condyles. The nails were quite rigid and caused fractures when first loaded in extension in 8/12 specimens. The fractures were longitudinal in the anterior part of the proximal fragments and was up to 6 cm long (Fig 4). However, although fractured, the fixation held the specimens together sufficiently for further testing.

Rush pins

The Rush pins showed less satisfactory fixation distally compared to the Zickel nails. When loaded, both in extension and abduction, the hooked end of the nails cut through the condyles (Fig 5). Only

one specimen had a true fracture which, however, did not prevent the other tests apart from residual stability, being performed.

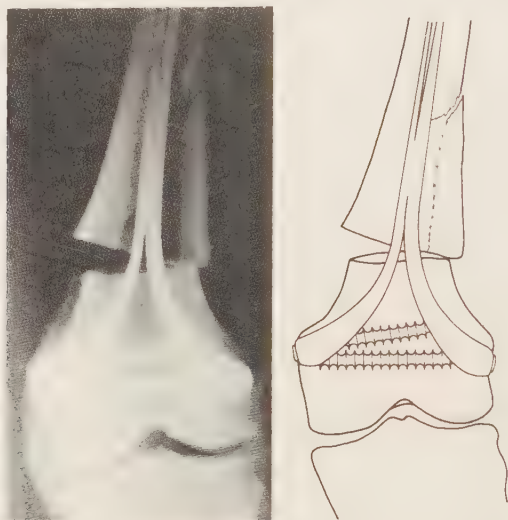


Fig 4. Antero-lateral fracture of the distal end of the proximal femoral fragment in experimental Zickel fixation. Pair n:o 5 after first test in extension.

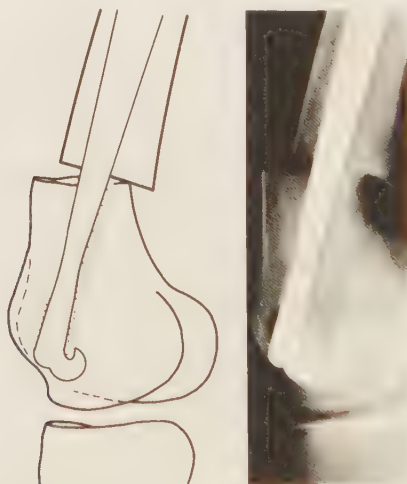


Fig 5. Enlarged hole of distal fragment of Rush fixation. Pair n:o 3 after first extension and abduction.

Ender nails

The Ender nails showed the same tendency as the Rush pins to cut through the condyles. Small compression fractures appeared at the joint surface of the lateral femoral condyle in 2/3 when loaded in extension. They all showed residual stability.

ECS

The ECS had a reliable distal stability through the condyles because of the coupled cancellous screws as opposed to the Rush and Ender nails. In 3/9 tests after extension a small longitudinal fracture on the anterior aspect of the proximal fragment appeared. Residual stability was registered in 8/9 specimens.

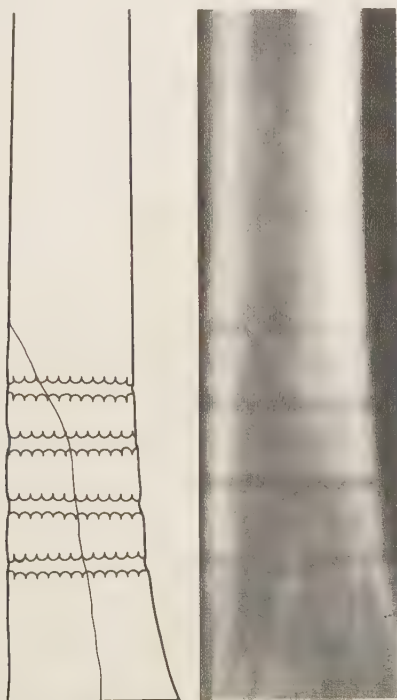


Fig 6. Longitudinal fracture of the proximal fragment splitting the bone into two halves in AO osteosynthesis. Pair n:o 7 after first extension.

Blade plate

The AO blade plate resisted heavier loads than the others in most of the cases and had the greatest stiffness both in extension and abduction. However, in extension tests this type of fixation produced fractures in all specimens. The fracture extended through the screw holes in the proximal part separating the bone into two halves (Fig 6). In abduction the plate bent and held the fractured ends apart and angulated. The residual stability could only be tested once.

CALCULATIONS FOR NEED OF EXTERNAL SUPPORT

For passive lifting of a normal leg (male 175 cm, 70 kg) by grasping the big toe with the patient sitting or supine, the moment, 6 cm above the knee joint level, was calculated as follows. The total weight of the entire leg from the groin to the toes is approximately 10 kg and the part distal to the osteotomy is 5 kg (B).

$$\frac{46 + 6}{2} = 26 \text{ cm}$$

The moment is $0.26 \times 5 = 1.3 \text{ kpm} = 13 \text{ Nm}$.

Raising the leg by lifting the heel (about 2 cm more proximal) gives approximately 12 Nm. If the patient's body weight is less or the leg is thinner or shorter, the moment by passive lifting under the heel is less. The risk for angular deformity more than 10° on such a manoeuvre could be estimated and the need for external support assessed. In Table 7 the fixation devices are listed where the moment necessary for a deflexion of 10° at the osteotomy in the tests exceeded 12 Nm. The Rush pins and the Ender nails were insufficient without external support, while the condylar plate was sufficient in the performed tests. The Zickel and the ECS fixation devices both failed in a 96-year-old specimen (Pair 14). However, in most tests they were judged sufficient without external support.

Table 7. Number of tests where the moment at the osteotomy site, necessary for a deflection of 10° , exceeded 12 Nm - and total number of tests.

Type	Extension	Abduction
AO condylar plate	3/3	2/2
Rush	0/3	3/3
Zickel	11/12	10/12
Ender	1/3	1/3
ECS	6/9	5/8

DISCUSSION

The most widely used surgical techniques for distal femoral fractures, AO condylar plate and Rush pinning have proved less successful in the elderly.^{8,11,12} To increase stability of internal fixation with a condylar plate, Benum (1977)¹ has used bone cement in 14 female patients, with previous fractures, disabling diseases or osteoporosis. All but one healed but no mention was made of the range of motion. This method was interesting but limited to extra-articular fractures.

Rush pin fixation involves problems at the distal end because the heads will cut through the cancellous bone of the condyles. In 1968 Rush therefore suggested a modified "loop" and considered it a great aid both in femoral and tibial condyles.¹¹ We have to date, however, not retrieved any reports of fractures thus treated. The device does not include condylar fixation.

To improve the fixation in the distal femur, Zickel¹⁵ designed a blade-shaped nail with an opening in the nail distally for a cancellous screw traversing both condyles. One nail is inserted through each condyle. We have used the method in two cases in 1978.⁶ However, during insertion the nails tended to lift the distal fragment anteriorly and distract the condyles in bicondylar fractures. This was caused when the flat nails passed into the curved femoral shaft.

In October 1978 a new technique with intramedullary elastic nails of Ender type connected to two transcondylar cancellous screws by a metal coupling was designed (ECS semi-elastic fixation device).⁵ This device could more easily be applied than the Zickel especially in bicondylar fractures. The whole length of the femur could be used and rotational stability attained by anchorage of the tips of the nails in the trochanter and neck of the femur.

The experimental model used here differs from the clinical situation in many aspects. Clinically the soft surrounding tissue supports the fracture and the uneven or jagged appearance of a fracture decreases the risk for displacement and may increase rotational stability.

The ECS (semi-elastic) and the Zickel fixation devices have similar biomechanical properties. Both give sufficient condylar fixation and flexible adjustment of the fragments. After testing in abduction the elastic devices re-attained the original position while the AO condylar plate distracted the bone ends. Unnecessary weakening of already fragile bone by perforating screw holes in the femoral shaft are avoided with the intramedullary types, which is considered important in this group of patients where 84 per cent are over 50 years and more than half had sustained previous fractures or diseases resulting in osteopenia.⁸ In patients without bone fragility a condylar plate with screws creates a more rigid fixation and allows immediate joint motion with little risk of mechanical failure.

SUMMARY

Five devices for distal femoral fractures, the AO condylar plate, Rush pin, Ender nail, Zickel and a new, semi-elastic device, were tested for stability in cadaver femur. Fixation was carried out in 17 pairs of osteotomized post mortem preparations from patients above the age of 60. The specimens were submitted to constant bending rate and the load deformation was registered. The fixation with the condylar plate was strongest and showed the lowest flexibility.

The Ender and the Rush pins showed a tendency to lose their condylar stabilization early. This was less pronounced with the Zickel nail which, however, tended to displacement at the osteotomy site during insertion and fractured the proximal fragment due to the limited bending ability of the blade construction. The new, semi-elastic device (ECS) was constructed to meet the special circumstances with bone fragility. It consists of two Ender nails, one inserted from each condyle and each connected to two cancellous screws traversing both condyles. It combined easy insertion with moderate flexibility and high residual strength. In extension it deflected 40° without influencing residual stability. It seems to be an interesting alternative to rigid internal fixation or traction in bed for osteoporotic patients with distal femoral fractures. It combines the possibility of a rigid screw fixation in the condylar part with an elastic adjustment in the femoral shaft above.

ACKNOWLEDGEMENTS

Financial support: This investigation was supported by grants from "Förenade Liv" Mutual Group Life Insurance Company, Stockholm, Sweden.

REFERENCES

1. Benum, P.: The use of bone cement as an adjunct to internal fixation of supracondylar fractures of osteoporotic femurs. *Acta Orthop Scand* 48(1):52-56, May 1977.
2. Chiron, H.S., Tremoulet, J., Casey, P. and Müller, M.: Fractures of the distal third of the femur treated by internal fixation. *Clin Orthop* No 100:160-170, 1974.
3. Gunterberg, B., Romanus, B. and Stener, B.: Pelvic strength after major amputation of the sacrum. *Acta Orthop Scand* 47: 635-642, 1976.
4. Gunterberg, B., Goldie, I., Slätis, P.: Fixation of pelvic fractures and dislocations. An experimental study. *Acta Orthop Scand* 49, 278-286, 1978.

5. Kolmert, L., Egund, N., Persson, B.M.: Internal fixation of supracondylar and bicondylar femoral fractures with a new semi-elastic device. Accepted for publication in Clin Orthop.
6. Kolmert, L. and Persson, B.M.: Two types of Zickel nails for femoral fractures proximally and distally. Läkarsällskapet Medicinska Riksstämman, Stockholm, Dec 1978.
7. Kolmert, L. and Persson, B.M.: Supracondylar femoral fractures as a complication to Ender nailing of trochanteric fractures. A new device for osteosynthesis. Arch Orthop Traumat Surg 97(1): 51-55, 1980.
8. Kolmert, L. and Wulff, K.: Epidemiology and treatment of distal femoral fractures in adults. Accepted for publication Acta Orthop Scand.
9. Müller, M.E., Allgöwer, M. and Willenegger, H.: Manual of internal fixation. New York, Springer Verlag, 1970.
10. Neer, C.S., Grantham, S.A. and Shelton, M.L.: Supracondylar fractures of the adult femur. A study of 110 cases. J Bone Joint Surg 49-A:591-613, 1967.
11. Rush, L.V.: Dynamic intramedullary fracture fixation of the femur. Clin Orthop No 60:21-27, 1968.
12. Shelton, M.L., Grantham, S.A., Neer, C.S. and Singh, R.: A new fixation device for supracondylar and low femoral shaft fractures. J Trauma 14:821-835, 1974.
13. Schatzker, J. and Lambert, D.C.: Supracondylar fractures of the femur. Clin Orthop No 138:77-83, 1979.
14. Stewart, M.J., Sisk, T.D. and Wallace, S.L.: Fractures of the distal third of the femur. J Bone Joint Surg 48-A:784-807, 1966.
15. Zickel, R.E., Fietti, V.G., Lawsing, J.F. and Cochran, G.V.B.: A new intramedullary fixation device for the distal third of the femur. Clin Orthop No 125:185-191, 1977.

INTERNAL FIXATION OF SUPRACONDYLAR AND BICONDYLAR
FEMORAL FRACTURES WITH A NEW SEMI-ELASTIC DEVICE

by

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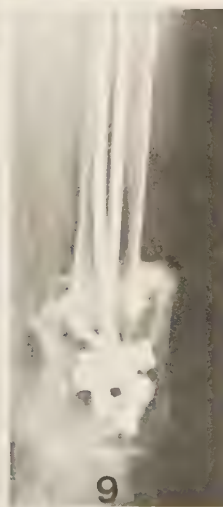
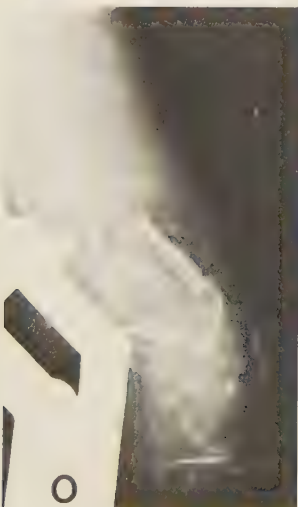
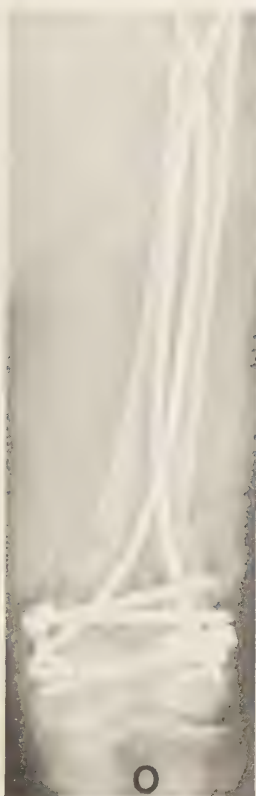
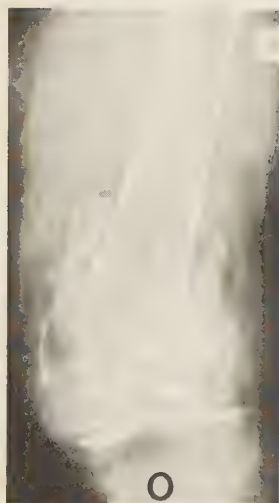
INTRODUCTION

Most fractures of the proximal two thirds of the femur can be satisfactorily stabilized by available surgical methods. Extended periods of traction in bed are avoided allowing for almost immediate mobilization following surgery. For the less common fractures of the distal third of the femur, traction in bed has been the recommended method.^{16,23} However, intramedullary fixation^{18,29} and different onlay methods with metal plates (Blount reverse blade plate,²⁶ AO condylar plate,¹⁵ Judet²⁸ and Neer²² plates) have widened the scope of surgical management. In the very old these methods have often failed because of bone fragility; the majority of distal femoral fractures occur after age 60. We have therefore developed a fixation device which does not require mechanically normal bone (Fig 1 and 2).⁷⁻⁹ This semi-elastic device is based on a rigid screw fixation of the condyles and an elastic rod fixation to the shaft of the femur joined together by a special coupling piece. The device is inserted through small incisions on each side of the knee, avoiding wide exposure and minimizing risk of infection (Fig 3 and 4).

Previous reports have shown that the treatment of undisplaced distal femoral fractures in plaster and displaced unicondylar surgical with screws, resulted in an acceptable final outcome both with respect to short and long term follow ups.^{6,10} This prospective series therefore is focused on the more troublesome displaced bi- and supracondylar fractures. The purpose has been to avoid traction and mobilize the patients within a few days.

PATIENTS AND METHODS

From October 1978 through November 1980, 52 patients with 54 supra- and bicondylar femoral fractures, were treated in Lund. The material comprised fractures entirely or partly within the distal third and unsuitable for stabilization by Küntscher nailing. In order to assimilate a large base material and thereby gain experience in the management of these fractures, five hospitals in the neighbourhood re-



a

b

c

Fig 1. Case 32, female aged 73 with previously known coxarthrosis of the left hip. She sustained a bicondylar and comminuted fracture from a fall at home. Osteoporotic a) on admission b) after reduction and semi-elastic fixation c) at 9 months



Fig 2. Case 9, female aged 71 with previous trochanteric fracture of the right hip treated with a Thornton nail-plate. During epileptic seizures she sustained a left-sided trochanteric fracture and rightsided supracondylar fracture (illustrated) a) on admission b) at 25 months

ferred their patients (or records and radiographic material) with distal femoral fractures to Lund.

Thirty-four patients were treated surgically (Table 1). The mean age was 65 years (range 15-92 years). Four patients, all females, died within three months following injury. Case 1, age 96, expired from a gastric bleeding one week postoperatively. Cases 3 and 6, age 78 and 84, died of cardio-pulmonary disease 2 and 3 months following surgery. Case 34, age 67, with cerebral contusion and bilateral ankle fractures following a road traffic accident, died at three months not having regained consciousness. Cases 3, 6 and 34 showed normal callus formation up to the time of death. One patient, case 4, refused to participate in the follow up, thus leaving 29 patients with 29 fractures.

Twenty-one of the patients suffered from other diseases or fractures primarily of the hip, and case 17 was a long term drug addict (Table 1). Preceding disability of the unfractured leg, concomitant injuries and osteopenia were recorded.

The degree of trauma¹ was classified as minor in 16 patients who had stumbled at ground level (F). The degree of trauma was classified as major in 13 patients where fall from a height, crush injuries (H) or traffic accidents (T) was the causative factor. All but one fracture were closed injuries.

Twenty-one fractures in 19 patients were treated non-surgically and are briefly summarized (Table 2). The mean age was 67 years (range 21-95 years). Sixteen were classified as supracondylar and 5 as bi-condylar. Fifteen fractures were undisplaced and treated in plaster from the first week, and six were treated in traction.

Male aged 79, 10 years of cardiomyopathy and three previous fractures of the injured leg - treated in traction because of poor general condition.

CODE FOR TABLE 1 and 2.

SEX:	M	Male
	F	Female
PREVIOUS DISEASE	Addict	Drug addict
	Adip.	Adipositas
	Ast.	Astma
	Ang.p.	Angina pectoris
	Art.scl.	Arteriosclerosis
	Ca.mam.	Cancer mammae
	CDH	Congenital Disease Hip
	C.A.	Coxarthrosis (Osteoarthritis)
	Cir.	Cirrhosis
	C.P.	Cerebral Paresis
	Dem.	Dementia mentis
	Ep.	Epilepsy
	Et.	Ethylism
	G.A.	Gonarthrosis (Osteoarthritis)
	H-pares	Hemiparesis
	Lymf.	Lymphoedema
	M.S.	Multiple Sclerosis
	O-myel	Osteomyelitis
	Reckl.	Mb Recklinghausen
	R.A.	Rheumatoid Arthritis
	T.H.R.	Total Hip Replacement
	T.I.A.	Transitory Ischemic Attacks
	Ulc.cr.	Ulcus Cruris
	Vert.	Vertigo
FRACTURES and INJURIES	A	Arm
	B	Bicondylar femoral
	C	Costae
	Com	Commotio
	H	Hip
	M	Malleolar
	P	Patellar
	PT	Pneumothorax
	S	Supracondylar femoral
	T	Tibia
	TC	Tibial condylar
WALKING CAPACITY	A	Without external support
	B	Sticks or crutches
	C	None-walker, only with assist
	b	bed-ridden
	w	wheel-chair
TIME	Mo	Months
TRAUMA	T	Traffic
	H	Other violent
	F	Fall at ground level
RESULTS	E Excellent	G Good
	F Fair	P Poor

Table 1:1. Surgical treatment for displaced supracondylar fractures (type b and c) and results at follow up. The patients are numbered consecutively.

Case Type n:o	Patient				Trauma		Operation		Follow-up										
	Sex	Age	Previous Disease	Fract	Walk capac	Ost leg pen disabl	Other leg	Concom injury	Open (+)	Type	Compl	Varus ^o (+)	Ant ^o (+)	Short- ened	OBS mo	Function Subj IM			
b	5	F	58	-	H	A	-	-	T	Com	-	I	-	3	6	0	26	+	E
	9	F	71	Ep	H	B	+	+	F (EP)	H	-	I	-	-2	8	0	25	+	E
	14	M	51	-	-	A	-	-	H	-	-	I	Thromb	3	6	0	15	-	F
	19	F	48	Cir CDH (THR)	-	B	+	-	F	-	-	I	-	1	8	0	13	-	F
	21	F	74	G.A., Ast	T	A	+	+	F	-	-	I	-	-4	6	0	13	+	E
	22	F	87	-	H	B	+	+	F	-	-	II	-	-6	0	1	9	+	G
	23	F	15	-	-	A	-	-	T	-	-	II	-	0	0	0	13	+	E
	26	F	86	Diab	-	A	+	+	-	H	-	II	-	2	13	2,5	7	+	G
	30	F	90	-	H	B	+	+	-	F	-	II	-	-3	5	1	8	+	E
	31	F	15	-	-	A	-	-	T	-	-	II	-	3	4	0	11	+	E
	32	F	82	Dem., G.A.	H	C _b	+	+	F	-	-	II	-	10	6	4	5	+	E
c	10	F	81	Diab. Cor Ulc cr G.A.	-	C _b	+	+	F	-	-	I	-	9	13	3	29	+	E
	12	F	92	-	H	B	+	+	-	F	-	I	-	-2	6	1	24	(+)	G
	13	F	62	R.A. Ca mam	-	B	+	+	-	T	-	I	-	7	10	0	16	(+)	G
	16	M	38	Et., o-myel F TC	A	+	+	-	H	-	-	I	-	6	8	2	7	+	G
	18	F	46	-	-	A	-	-	T	-	-	I	-	8	7	0	14	(+)	F
	20	F	57	-	-	A	+	+	-	F	-	I	Coupl	6	11	2,5	19	-	P
	24	M	80	M.S. Palsy	-	C _w	+	+	F	-	-	II	-	-1	5	3	8	+	E
	27	F	85	H-pares	-	C _w	+	+	-	F	-	II	-	7	4	1	7	+	G
	28	F	89	Diab, TIA, C.A-	-	B	+	+	-	F	-	II	-	-3	-3	3	6	+	G

Table 1:2. Surgical treatment for displaced bicondylar fractures (type b and c) and results at follow-up.
The patients are numbered consecutively.

Case Type n:o	P a t i e n t				T r a u m a		O p e r a t i o n		F o l l o w - u p									
	Sex	Age	Previous Disease	Fract	Walk capac	Ost leg pen disabl	Other leg	Concom injury (+)	Open	Type	Compl	Varus ^o (+)	Ant ^o (+)	Short- ened	OBS mo	Function Subj	IM	
b	2	F	74	CDH (THR)	-	A	+	+	F	-	I	-	-2	0	2	28	+	E
	25	F	69	Adip Lymf	-	A	+	+	H	-	II	-	-2	0	1.5	7	+	E
c	7	F	59	Adip Et	-	A	-	-	F	-	I	Emb	7	-7	3.5	25	-	P
	8	M	55	-	-	A	-	-	T	C.P. PT +	I	Non-u	4	20	3	27	-	P
	11	F	42	Adip Ast, T,TC	-	A	-	-	F	-	I	-	3	8	2	25	-	G
	17	M	28	Addict	-	A	-	-	T	A	I	-	7	16	0	15	-	F
	29	F	77	Diab Vert H(THR)	-	B	-	-	?	-	II	-	-2	0	2	7	+	G
d	15	M	69	-	-	A	-	-	T	M.C. PT -	II	-	3	20	1	17	+	E
	33	F	73	C.A.	-	A	+	-	F	-	II	-	-3	10	2.5	11	-	F

Table 2. Non-surgical treatment of supra- and bicondylar femoral fractures.
The patients are numbered consecutively.

Sex	Age	Prev disease	Prev fractures	Walk Side	capac Side	Fracture Type	Displ	Open	Treatment
M	70	Cir (coag def)	-	R+L	B	S	L	+	Cast-b
F	57	Ep H-pares L	-	-	Cw	B	L	-	Plaster
M	79	Ang p TIA	H,T,TC	R	B	S	R	-	Tract 4w+Cast-b
*F	81	Diab Ang p Ulc cr	-	-	Cb	S	L	+	Tract 6w - op (bed-sores)
F	94	Art scl	TC,M	L	Cb	S	R	-	Plaster
F	51	R A (contract)	-	-	Cw	S	L	-	Plaster 6 w
F	66	M S	-	-	B	S	R	-	Plaster
F	67	-	H (Ender)	L	A	S	L	+	Tract 3 w+Plaster (perop)
F	82	Knee Arthrodesis	-	R	B	S	R	-	Plaster
F	81	CP+Pares, cortisone	-	-	Cb	S	L	+	Died 24h after admitt (DIC?)
M	76	-	-	-	A	S	L	-	Plaster
M	21	Dem	-	-	A	B	L	-	Plaster
M	25	-	-	-	A	S	R	+	Tract 5 w + Cast-b (gun shot)
M	25	-	-	-	A	S	L	+	Tract 5 w + Cast-b (gun shot)
M	54	R A Marmor-prost	-	L	A	S	L	-	Plaster - Cast-b
F	95	Dem	-	-	Cw	B	R	-	Plaster
F	80	-	-	-	A	S	R	-	Plaster
F	73	C A, G A, L	S	R	B	B	L	-	Plaster
F	78	-	H	L	B	S	L	-	Plaster
F	78	-	H	R	B	S	R	-	Plaster
F	75	Art scler	-	-	C	B	L	-	Plaster

* Also in surgical group (case n:o 10)

Female aged 81, diabetes, heart disease and bed-ridden because of weakness. She was first treated in traction and developed bedsores after six weeks - transferred to the surgical group for stabilization (case 10).

Female aged 67, with iatrogenic supracondylar fracture during Ender-nailing for trochanteric hip fracture - treated in traction for three weeks and then in plaster.

Male aged 25, with bilateral open supracondylar fractures due to gun-shot wounds - treated in traction for five weeks and then in cast-braces.

The last of the 21 fractures treated in plaster or traction was a female aged 81, with cerebral palsy, left hemiparesis and bed-ridden before the fracture. She died 24 hours after sustaining her displaced fracture.

Classification⁶

The classification of the fractures in the supracondylar and bicondylar types was as follows.

Supracondylar fractures: a) undisplaced, b) displaced, c) displaced with comminution and/or shortening.

Bicondylar fractures: a) undisplaced, b) displaced only within the supracondylar and the intercondylar fracture, c) displaced both in the supracondylar and the intercondylar fracture, d) displaced in the supra- and intercondylar fracture with concomitant transcondylar (traversing articular surface) fracture.

Preoperative care

On admission tibial traction was applied. The high incidence of previous disease emphasized the importance of preoperative radiographic examination of the entire femur.⁶ In cases of major trauma intensive care was the rule. Dextran infusion as a thrombo-embolic prophylaxis was started immediately. The operation was scheduled for the next or immediate following day.

Indications for surgical treatment

The main indications for surgery were displacement and comminution of the fractures. Nursing aspects contributed to the surgical treatment of case 10 and 32. Case 24, a male aged 80, with paralysis due to multiple sclerosis and bound to a wheel-chair, was stabilized after 10 days and could sit comfortably without external support following surgery. Case 8, a male aged 55, sustained an open, comminuted, bicondylar femoral and a patellar fracture in the same knee following a traffic accident. Because of several rib fractures and a pneumo-thorax he was treated in a respirator for three weeks, during which time the wound from the open fracture healed. Operation was performed after four weeks, care being taken to avoid opening the fracture. Surgery in the other patients was performed 1-3 days after admission.

Operative technique⁷

The purpose of a semi-elastic fixation is anatomical reduction and rigid fixation of the condyles allowing for an elastic adjustment of these to the femoral shaft. This was achieved with 2-4 intramedullary nails, 2 coupling-pieces and 2-4 cancellous screws. The intramedullary elastic nails were connected to the cancellous screws on each side by a coupling piece.

The nails were available in lengths from 22 to 49 cm. Femurs without previous fractures or endo-prosthesis were treated with one nail from the medial condyle with the tip of the nail reaching the femoral neck and one nail from the lateral condyle with the tip of the nail reaching the trochanteric region. With the tips of the nails in different parts of the proximal femur and the distal parts of the nails well anchored with cancellous screws, resistance to rotation was attained. When a total hip replacement or a nail and plate occupied the proximal space the shorter nails, were used. Sometimes it was possible to thread the nail along side the screws of a plate in the proximal third of the femur (Fig 2). When a total

hip replacement necessitated shorter nails, these ended 1-2 cm from the distal tip of the cement to allow for some shortening. The first 21 patients were operated with hooked ends to the nails as in the Rush pins (Fig 3 a). Thereafter straight nails, flattened at the end and with a hole for the extractor were designed (Fig 3 b). These have been used in more than 35 patients to date.

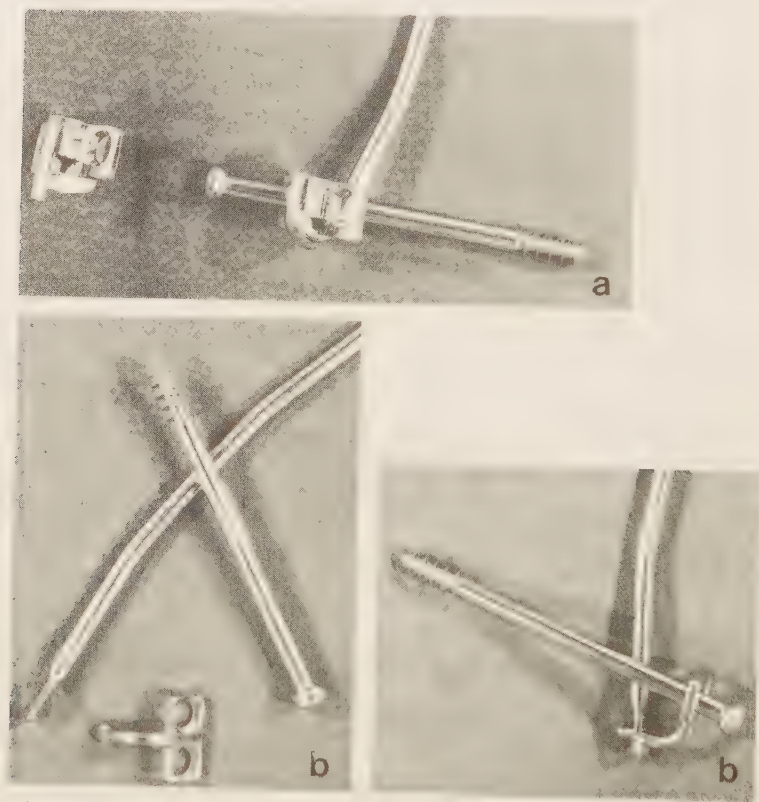


Fig 3. Semi-elastic fixation device with coupling piece separately and applied to the nail with the first screw inserted. The second screw completes the fixation which is similar medially and laterally.

- a) Mark I. The hooked Ender-nail and the coupling piece applied. It is locked by bending the little flange over the distal end of the nail.
- b) Mark II. The flat-ended Ender-nail with the coupling piece applied. This is locked by turning the plate through 90° proximally before the screws are inserted. Two nails could be applied to the same coupling-piece.

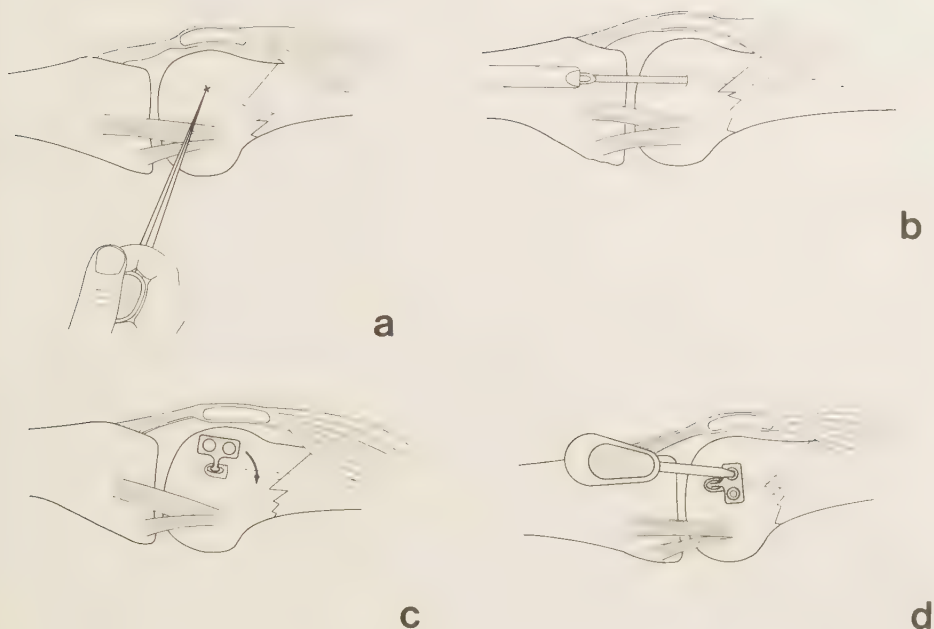


Fig 4. Technique for insertion of semi-elastic fixation.

- a) Predrilling with an awl, $1\frac{1}{2}$ cm above the knee-joint, between the anterior border of the joint and the femoral insertion of the collateral band.
- b) The first nail is introduced until it has entered the proximal fragment. It fasciliates by manipulation of the fracture the insertion of the second nail from the other side. When both nails have entered the proximal fragment further introduction is carried out alternately a few centimeters at a time.
- c) Predrilling with an awl through the hole in the nail precedes the application of the coupling piece which is then turned through 90° proximally and locked (arrow).
- d) Two cancellous screws are inserted, one on each side of the nail. With intercondylar fractures and/or osteoporotic bone, at least one screw from each side has to reach the other cortex for firm stabilization.

The coupling-piece for the first type of nail was connected to the hooked end of the nail by a small flange (Mark I, Fig 3 a). This flange broke in one case before healing occurred and had to be replaced by the new design of nail and a new type of coupling piece (Mark II, Fig 3 b). This second type was easier to insert and was locked by turning the coupling-piece through 90° (Fig 4 c-d). At least two nails can be attached to the same coupling-piece.

Two cancellous screws were inserted through each coupling-piece (Fig 4 d). These kept the condyles together, prevented cutting through the condyles and extrusion of the nails and locked the system preventing rotation. The screws reached the opposite cortex in cases with a bicondylar fracture or osteoporotic bone.

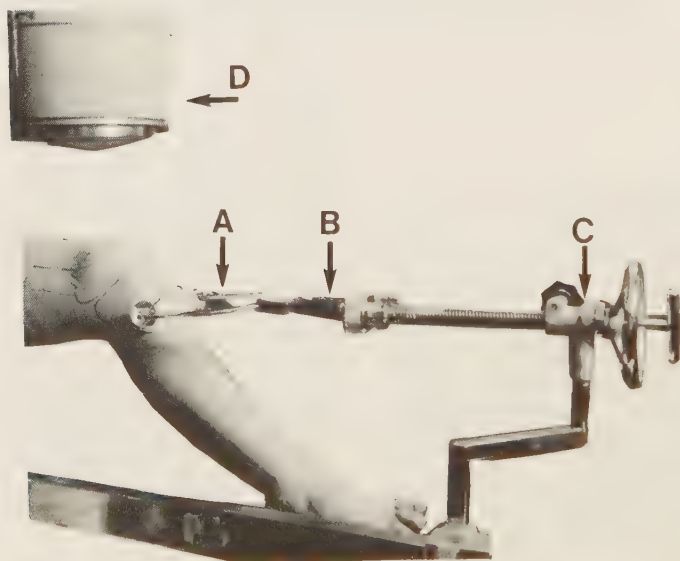


Fig 5. Extension apparatus with a metal extension connected to the traction stirrup. With this technique the lower leg, freely hanging, is bent $30-40^{\circ}$ relaxing the gastrocnemius muscles and counteracting the tendency towards anterior angulation.

- A Traction stirrup
- B Metal extension
- C Extension apparatus
- D Image intensifier

The operation was performed under epidural or general anesthesia. The tibial traction stirrup was connected to the orthopaedic table by a metal extension (Fig 5), allowing the knee to be flexed 30-40° in order to relax the gastrocnemius muscles. Instead of a sling around the hip a well-padded pelvic pin-support counteracted the traction. This decreased venous congestion and per-operative bleeding. The fracture was reduced with the aid of an image intensifier before the knee region was prepared.

Incisions were made from the level of the knee joint proximally over the lateral and medial condyles, about 5-7 cm in length. When necessary one incision was extended for open reduction of the fracture.

For displaced intercondylar fractures, temporary fixation was obtained by Kirschner wires or bone clamps and cancellous screws. For undisplaced intercondylar fractures and for supracondylar fractures, immediate predrilling with an awl was made for the nail between the anterior border of the joint and the femoral insertion of the collateral band (Fig 4 a). If the fracture was close to the knee-joint, the nail was inserted from a more distal point but at least 1½ cm above the joint. When situated more proximal, the nail was inserted just above the condyle (Fig 1). The length and the shape of the intramedullary nail was checked using the image intensifier with the nail against the thigh. Prebending of the nails was regarded as important to retain an appropriate position of the reduced fracture. The configuration of the medial femoral cortex necessitated more prebending than for the lateral side; the lateral nail should be straighter than the medial.

Because of the rigid distal anchoring of the nails sliding must take place in the proximal shaft. The length of the nails should therefore allow for 1-2 cm of sliding proximally (Fig 6) (this can be compared to Ender-nailing where sliding is possible at the distal end).

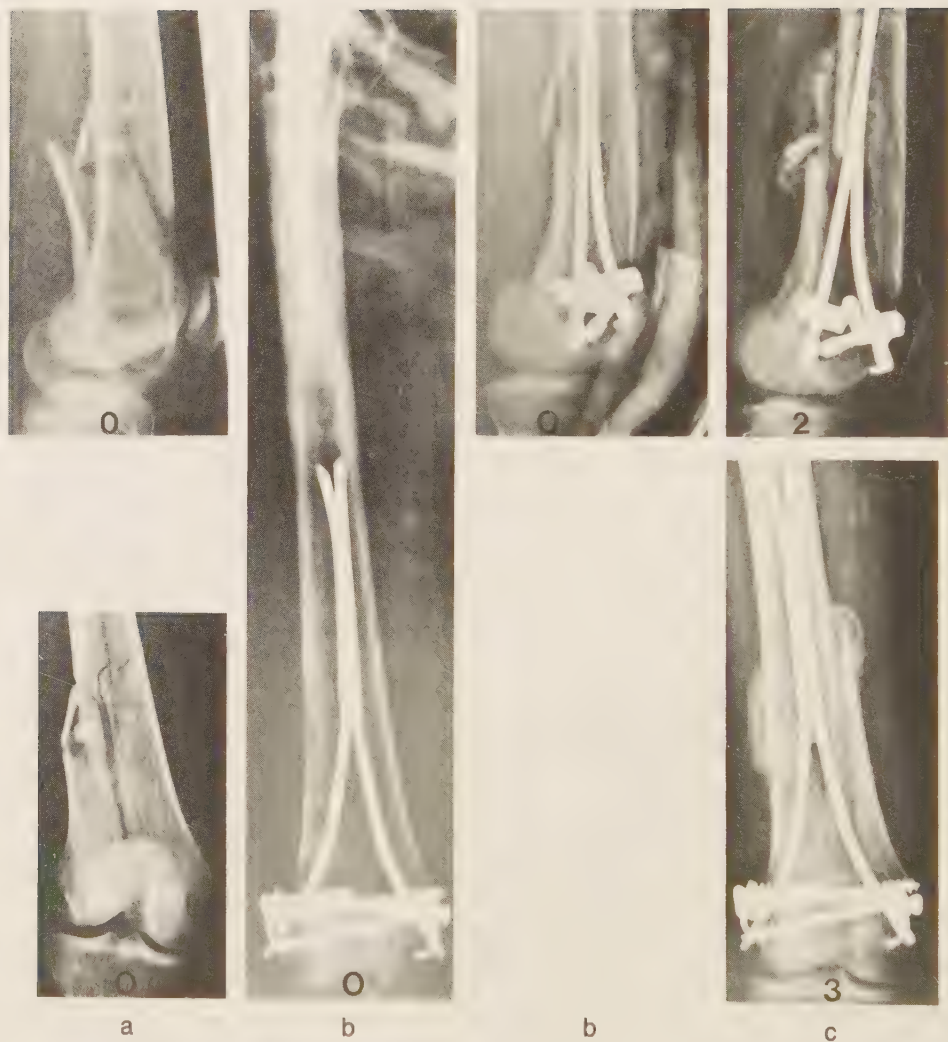


Fig 6. Case 29, female aged 77, with diabetes and total hip replacement following a fracture 1977. She fell during an attack of vertigo and sustained a bicondylar fracture. a) on admission, b) after reduction and semi-elastic fixation, c) callus of 2 and 3 months.



Fig 7. Case 8, male aged 55 sustained an open, comminuted fracture including fracture of the patella in a traffic accident. Treated in traction for four weeks prior to nailing because of concomitant costal fractures with pneumo-thorax. The nails were removed at 8 months due to some extrusion. The fracture was considered stable when examined under anaesthesia. Delayed union, however, necessitated re-operation with a cancellous bone graft, following which the fracture united uneventfully. Final leg length difference 3 cm. a) postoperative, b) at 18 months.

Through a cortical hole made with an awl the first nail was inserted until it had entered the first centimetre of the proximal fragment. With this in place, the fracture could be manipulated to support the insertion of the second nail. The nails were then inserted at each side alternately. When the final position of the first nail was reached, the coupling piece was applied. This both marked the position of the nail and prevented it from sliding intramedullarily. To fill the intramedullary space, another nail when required was inserted at each side to lie adjacent to the first and using the same coupling-piece for both.

The coupling-piece was turned through 90° to lock it (Fig 4 c). This turning points the vertical arm distally and the screw-holes in the transverse plate proximally on each side of the nail to lock the system against flexion-extension displacement. Predrilling with an awl and countersinking was necessary in healthy bone before insertion of the screws which were directed to the opposite cortex for proper fixation. The length, position and direction of each cancellous screw was facilitated by having two incisions. In cases with a more proximal insertion of the nails, the screws were directed slightly downwards. A final check of all fixation material was made using the image-intensifier before the wound was closed in layers. An anterior plaster slab was used for the first two weeks to reduce pain and swelling.

Postoperative care

The position was checked radiographically immediately following surgery, at two weeks and then every fourth week until union occurred. On the first post-operative day, the patient was mobilized with crutches or a walking-frame. Patients with transverse fractures were permitted to bear weight without external support from the start; those with oblique or comminuted fractures were allowed to mark time, immobilized in an anterior plaster slab. Two weeks post-operatively the sutures were removed and the plaster changed to a

hinged cast-brace permitting partial knee motion depending on the type of fracture and its comminution.

Clinical examination

Both the hip and the knee joints were examined. Range of motion, instability and leg length difference measured from the anterior superior iliac spine to the medial malleolus were noted. Pain and walking distance was evaluated as was the patient's opinion regarding function of the leg, compared to the pre-traumatic state.

The functional assessment was summarized (Table 3) according to our assessment sheet in the eight year study from Lund and Malmö (L M)¹⁰ with regard to range of motion, pain, angular deformity and shortening. The patellar joint was examined particularly for pain on palpation and retropatellar bony crepitation, indicating loss of joint cartilage.

Table 3. Assessment of results Malmö-Lund (M L) 1982.

Result	Knee motion	Pain	Angular deformity	Shortening
Excellent	Full extension and 120° of flexion	None	None	Less than 1 cm
Good	Full extension and 90° of flexion	None or occasionally	Hardly visible	Less than 2 cm
Fair	Less than 10° extension defect, more than 60° of total motion	Slight pain always	Less than 10° of varus or valgus	Less than 3 cm
Poor	10° extension defect. Less than 60° of total range of motion	Constant and severe	10° varus or valgus or more	More than 3 cm

"Excellent" was reduced to "good" if one of the criteria for "good" was fulfilled. Two or more of the criteria for "good" reduced the result to fair. Two or more of the factors in the "fair" group resulted in classification as "poor". Due to a shorter observation time and the number of elderly patients with previous diseases and limited needs of function we have accepted limitations in range of motion somewhat further than e.g. Stewart. The results are listed in Table 2.

Radiographic examinations

The pre- and postoperative examinations were in most instances obtained by two perpendicular projections at right angles. At the follow-up a more complete examination was performed as follows.⁶

1. Whole lower limb radiographs were taken with the patient standing on the examined limb only, using two X-ray tubes with their central rays perpendicular to each other. The defined frontal plane was tangential to the most posterior aspects of the femoral condyles obtained by fluoroscopy in the lateral view. The lateral plane was perpendicular to the frontal and the radiograph included the knee and the distal two thirds of the femur.
2. Axial radiographs of the patellar joint in the standing position were performed at a suitable degree of flexion to visualize the joint.

The radiographic examination at the follow-up included both the lower extremities for comparison. Angulation in the sagittal axis of the fracture, varus (+) or valgus (-) deformity, was described by the lateral angle between the longitudinal axis of the femur and a line joining the most distal points of the femoral condyles. This was compared to the normal side. In the lateral view rotation in the transverse axis was assessed by the shape of the condyles and Blumensaat's line in the intercondylar fossa, compared to the contralateral side. Anterior angulation was the angle ventrally (+) between the shaft and condyles and posterior angulation was that dorsally (-).

RESULTS

Twenty-three of the 29 operations were performed by two of the authors; two other surgeons performed the remaining six. In the younger patients, the fixation devices were removed at 6-18 months; on the elderly, on occasion, especially with the Mark I type, where

following union extrusion of the nails occurred due to breakage of the flange of the coupling-piece in some cases. Cutaneous infection followed removal in case 11.

The time in weeks, when 0.5 and 0.9 of the patients began walking, were discharged from hospital and taking full weight (Table 4) showed that 0.9 were discharged from hospital 10 weeks after a bicondylar and 15 weeks after a supracondylar fracture.

Table 4. Mobilization following operated distal femoral fractures. Time in weeks for 0.5 and 0.9 of the patients; 'walk' included those returning to previous condition in bed or wheel-chair.

Type	N:o of cases	0.5			0.9		
		Walk	Discharged hospital	Full weight	Walk	Discharged hospital	Full weight
Bicond	9	0	8	10	0	10	17
Supracond	16	0	4	9	0	15	15

Complications

Case 14, male aged 51, sustained a crush injury of his knee when hit by a truck and developed phlebothrombosis. Because of a slight discharge from the lateral wound antibiotics were given. Cultures were negative. Case 7, with a bicondylar fracture, developed a pulmonary embolism and was treated with anticoagulants. Case 8 (Fig 7) had delayed wound healing. Following surgery at 4 weeks, he was immediately mobilized. The nails were extracted at 9 months when the fracture was considered to be united. He, however, developed a non-union and was reoperated some months later with a cancellous bone graft supported by plaster, following which union occurred uneventfully. In case 20, female aged 57, the coupling piece broke (the flange of the Mark I type), and was replaced by the Mark II type. Antibiotics were not prescribed routinely and no case of osteomyelitis occurred in the material.

Follow-up

The mean observation time for the 29 patients was 16 months (range 5-29 months) (Table 1). The follow-up showed 12 excellent results, 9 good, 5 fair and 3 poor (Table 3). Thus satisfactory results (excellent + good) were seen in 21 of 29 fractures. The pre-fracture function was taken into consideration and a bed-ridden patient therefore received a high score if the fracture was stable and painless, even though slight malposition remained. Sixteen patients felt that they had regained their pre-fracture function and two were better (cases 21 and 22); case 21 had a known gonarthrosis and the outcome resembled the effect of an osteotomy. Three patients thought that function was almost as before the fracture and eight were decidedly worse.

The angular deformity and shortening for the united fractures (Table 5) showed that the most common displacement was varus and anterior angulation. Twenty-seven patients showed an angulation in the frontal plane (varus or valgus) or less than 8° . One patient had 9° and one 10° . In the sagittal plane, 23 patients showed an angulation of less than 10° and 6 between 11° and 20° .

Table 5. Deformities and shortening of the healed fractures for the different anatomical groups. The figures illustrate the number of patients in each group. For abbreviations see classification

Type	V a r u s			V a l g u s		
	0-4 $^{\circ}$	5-8 $^{\circ}$	9-10 $^{\circ}$	1-4 $^{\circ}$	5-8 $^{\circ}$	9-10 $^{\circ}$
Sb	6	-	1	3	1	-
Sc	-	5	1	3	-	-
Bb	-	-	-	2	-	-
Bc	2	2	-	1	-	-
Bd	1	-	-	1	-	-
	9	7	2	10	1	0
Type	Anterior		Posterior		Shortening (cm)	
	0-10 $^{\circ}$	11-20 $^{\circ}$	1-10 $^{\circ}$	11-20 $^{\circ}$	0-2,5cm	>2,5 cm
Sb	10	1	-	-	10	1
Sc	6	2	1	-	6	3
Bb	2	-	-	-	2	-
Bc	2	2	1	-	3	2
Bd	1	1	-	-	2	-
	21	6	2	0	23	6

Shortening less than 1 cm was seen in 15 patients. All the previously healthy, except two, were in this group; case 8 (with non-union) ended up with 3 cm of shortening and case 20 (re-operated due to broken coupling-piece), with 2½ cm. Eight fractures resulted in shortening between 1 and 2½ cm. Shortening of more than 2½ cm was seen in 6 patients, case 20 (vide supra) and case 7, a re-operation following a technically inadequate nailing of a bicondylar fracture, and cases n:o 10, 24, 28 and 32, patients 80-89 years of age. The mean shortening was 1.4 cm.

Table 6. Range of knee motion at follow-up (contralateral side for comparison). Supracondylar fractures. For diseases and fractures see Table 1:1.

Type	Case		Age	Previous		OBS mo	Range of knee motion ^o	
	n:o	Sex		Disease	Fract		Fract.knee	Other knee
b	5	F	58	-	+	26	0-140	0-150
	9	F	71	+	+	25	10-100	20-70
	14	M	51	-	-	15	0-100	0-135
	19	F	48	+	-	13	10-110	0-140
	21	F	74	+	+	13	0-95	0-120
	22	F	87	-	+	9	5-90	0-120
	23	F	15	-	-	13	0-120	0-135
	26	F	86	+	-	7	5-90	5-130
	30	F	90	-	+	8	10-135	10-120
	31	F	15	-	-	11	0-150	0-150
	32	F	82	+	+	5	?*	?*
c	10	F	81	+	-	29	0-30	30-50
	12	F	92	-	+	24	0-95	0-120
	13	F	62	+	-	16	5-95	0-100
	16	M	38	+	+	7	10-55	0-140
	18	F	46	-	-	14	5-75**	0-140
	20	F	57	-	-	19	15-85	0-130
	24	M	80	+	-	8	0-95	0-105
	27	F	85	+	-	7	0-95	5-110
	28	F	89	+	-	6	10-80	10-120

* Bilateral hip and knee contractures

** Examined 2 weeks after removal of osteosynthetic device (semi-elastic nails for the supracondylar fracture and Rush pin from the tibial tuberosity for the tibial fracture).

The range of knee motion was compared to the contralateral side (Table 6 and 7). An attempt made to assess outward rotation of the leg, with the patient relaxed in the supine position, showed only one patient with an outward rotation of 20° . The frequency of previous fractures and current diseases made comparisons with the healthy knee or pre-fracture situation difficult in many cases.

Following bicondylar fractures seven of nine patients were painfree and without femoro-patellar crepitation on palpation; case 7 and 29 had bony crepitations and case 7 also had pain. The radiograms in this case showed patellar incongruence. Case 29 had bony contact between the patella and femur in the uninjured knee. Following supracondylar fractures, 14 of 20 were painfree and without femoro-patellar crepitation. Case 13 had an effusion in both knees; case 10 and 18 had pain in both knees. Case 26 and 27 had bilateral bony contact between the patella and femur but no pain and case 19 only had pain.

Table 7. Range of knee motion at follow-up (contralateral side for comparison) Bicondylar fractures. For diseases and fractures see Table 1:2.

Type	Case n:o	Sex	Age	Previous		OBS mo	Range of knee motion ^o	
				Disease	Fract		Fract.knee	Other knee
b	2	F	74	+	-	28	0-120	0-120
	25	F	69	+	-	7	0-95	0-100
c	7	F	59	+	-	25	0-90	0-135
	8	M	55	-	-	27	0-90	0-165
	11	F	42	+	T,TC	25	0-90	0-105
	17	M	28	+	-	15	0-105	0-160
	29	F	77	+	H	7	0-100	0-130
d	15	M	69	-	-	17	0-90	0-100
	33	F	73	+	-	11	5-55	0-125

DISCUSSION

In 1933 Mahorner and Bradborn¹² reported on 31 distal femoral fractures with a frequently unsatisfactory outcome to Russell traction. In 1945 Modlin¹³ reported on 23 fractures of the distal third of the femur treated by tibial traction, supplemented by vertical traction through the distal fragment of the femur, giving encouraging results. In 1956, White and Russin²⁷ showed that internal fixation with the reverse Blount plate with additional plates and screws resulted in 10 poor results and 3 cases of postoperative infection in 46 operated patients. In 1966, Stewart et al,²³ and in 1967, Neer et al,¹⁶ reviewing large materials from the last 20 years, recommended traction because of frequent malpositions, non-union and osteomyelitis from different methods of internal fixation. Traction at that time often meant until radiographic callus was noticed and clinical stability attained. Surgery was performed intramedullary, with long nails or rods, or onlay with different plates, straight or angled.

The Rush technique started with straight intramedullary rods and continued with dynamic fixation by bent pins. In 1968¹⁸ Rush stated: "The great mechanical problem in the supracondylar area of the aged, has been the loss of fixation by the heads of the pins cutting and migration into the osteoporotic condyles". He therefore supplemented a loop at the head end of the Rush pin; unfortunately no material with that device has thus far been published. Previous experiences of Neer et al¹⁶ had also shown that Rush pins provided inadequate fixation and did not allow knee motion and early discharge and in 1974 Neer (in collaboration with Shelton, Grantham and Singh)²² presented promising results with a new straight plate and screws in the treatment of this fracture.

The Swiss AO-School^{3,24} has focused on exact anatomical reduction and rigid internal fixation with liberal supplementing of bone grafts in severe cases. In 1979 Schatzker and Lambert,²⁰ in a care-

ful analysis of failures, reported on 36 patients treated by this method. They divided the patients treated "in accordance with the principles of rigid internal fixation" and "the others". There was one failure in the first group, where four of 18 were over 50 years, and nine failures in "the others", where 15 of 18 were over 50 years and they concluded that "these elderly patients with moderate to severe osteoporosis usually was a challenge beyond the surgeons ability".

Our results of bi- and supracondylar fractures from 1969 through 1976,¹⁰ showed 4/17 unsatisfactory results for the AO condylar plate, 4/5 for the Rush pin and 4/9 for the other operations. The failures included three infections with one osteomyelitis, which led to amputation, one broken plate and three non-unions. All unsatisfactory results except one were seen in patients over 50.

One problem in the management of distal femoral fractures seems to be that most orthopaedic surgeons seldom treat many patients with this fracture. In the 8 year study from the south of Sweden detailing 45 operated cases, only a few orthopaedic surgeons had had the opportunity of operating more than one case.

The problem described arising with condylar plates and Rush pins prompted us to use the Zickel supracondylar device in 1977.⁹ However, its use in two patients and in several biomechanical⁹ tests showed a tendency for the blade-shaped rods to rotate and lift the distal fragment forwards, especially in bicondylar fractures with distraction of the condyles.

To overcome these disadvantages a new, simple and flexible fixation device was constructed, based on nails and screws already in use at the clinic. With the connection of the coupling-piece the condyles were kept rigidly together and the elastic fixation permitted small movements in the femoral shaft.⁷⁻⁹ This semi-elastic fixation has now been used in a total of 56 patients, 34 of which are included in this study. In contrast to the large plates, used with compres-

sion, only small incisions over each condyle are required in most cases and the nails and coupling pieces are simple to insert and apply. The use of two long crossed intramedullary nails prevents torsion at the fracture site. The intramedullary space can be filled with two nails from each side using the same coupling piece. With these 4 nails the fractured ends fit closely together without displacement in the frontal or sagittal plane. The different lengths available allow for fixation despite previous surgery with a nail - plate or endo-prosthesis in the proximal part of the femur.

The functional results for femoral fractures treated in a hinged cast-brace after an initial six weeks of traction in bed as reported by Mooney et al¹⁴ and Conolly and King⁴ were impressive. In our study the external support from the anterior plaster slab followed by the cast-brace made early mobilization possible, immediately out of bed and moving the knee at two weeks.

The range of motion in the injured knee was compared to the contralateral knee (Table 6 and 7). Although precise conclusions on motion could not be drawn from this small material most of those previously healthy have attained 90° or a range well comparable to the other knee or with regard to their previous diseases or injuries. Seinsheimer²¹ found that younger patients gain greater knee motion than older and the same tendency was seen in this study. Attention is directed to the not seldom different pre-fracture general condition, type of trauma and fracture in the healthy patients below 50; two healthy cases before 50 year (23 and 31) in this study did not however, motivate further division of the material.

Comparisons regarding discharge from hospital was largely dependent on rehabilitation facilities outside the hospital, social home care and other amenities (Table 4). The time to full weight-bearing seemed comparable to other methods. The great advantage in comparison to our retrospective material was the immediate mobilization out of bed for all those who were mobile before sustaining a fracture.

Because this type of fracture is most frequent in the elderly osteoporotic patients, bone cement as a supplement to condylar plates was used by Benum² with good results in 14 patients. The rather difficult technique of securing condylar plates by the use of bone cement is one possibility when no other method is available. Contrary to Benum² and Schatzker and Lambert²⁰ we found it possible to stabilize even patients with osteopenia to allow for early mobilization without using bone cement which otherwise would seem to be advantageous in these fragile fractures.

Semi-elastic fixation adapts well to the brittle skeleton permitting overloading to result in small movements at the fracture site instead of breaking forces causing the fixation to loosen. The easy technique with small incisions on both sides, has been performed without the routine use of prophylactic antibiotics and no deep infections. No other operative technique has been used in the treatment of distal femoral fractures during the last three years and it seems to be equally suitable in the young healthy skeleton.

SUMMARY

Previous reports of failures in the elderly following surgery of distal femoral fractures prompted the development of a semi-elastic internal fixation device suited for the mechanically weak bone of the elderly. The fixation device consists of intramedullary elastic nails of Ender-type connected to cancellous screws at each condyle by a special coupling-piece. It was easily applied through small incisions. During a two-year period 54 fractures of the distal third of the femur were treated. Most patients were elderly suffering from current diseases or previous fractures on the ipsilateral side. The goal was twofold: to avoid traction in bed and start early mobilization. Fifteen undisplaced fractures were treated in plaster or cast-brace. Six fractures were treated in traction. Thirty-four displaced supra- and bicondylar fractures were operated with the new fixation device. No deep infections or osteomyelitis occur-

red. Direct mobilization was possible in all 34 cases, most with an external support of plaster for 2 weeks and a hinged cast-brace for 8 weeks. Twenty-nine could be followed up to union and the results, in these displaced supracondylar and bicondylar femoral fractures, were excellent in 12, good in 9, fair in 5 and poor in 3 patients.

The semi-elastic character of the system seemed to prevent those failures seen with the use of rigid internal fixation in osteoporotic bone.

ACKNOWLEDGEMENTS

Financial support for this study was provided by grants from Förenade Liv Mutual Insurance Company, Stockholm, Sweden, and Stiftelsen för bistånd åt vanföra i Skåne, Helsingborg, Sweden.

REFERENCES

1. Alffram, P.-A., Bauer, G.C.H.: Epidemiology of fractures of the forearm. *J Bone Jt Surg* 44-A: 105-114, 1962.
2. Benum, P.: The use of bone cement as an adjunct to internal fixation of supracondylar fractures of osteoporotic femurs. *Acta Orthop Scand* 48(1):52-56, May 1977.
3. Chiron, H.S., Trémoulet, J., Casey, P., and Müller, M.: Fractures of the distal third of the femur treated by internal fixation. *Clin Orthop* 100:160-170, 1974.
4. Conolly, J., King, P.: Closed reduction and early Cast-Brace ambulation in the treatment of femoral fractures. Part I. Conolly, J., Dehne, E., Lafollette, B., same title Part II. *J Bone and Joint Surg* 55-A, No 8: 1559-80 Part I, 1581-99 Part II, 1973.
5. Della Torre, P., Aglietti, P., and Altissimi, M.: Results of rigid fixation in 54 supracondylar fractures of the femur. *Arch Orthop Traumat Surg* 97:177-183, 1980.

6. Egund, N., and Kolmert, L.: Deformities, gonarthrosis and function after distal femoral fractures. *Acta Orthop Scand*. Accepted for publication.
7. Kolmert, L.: Operative technique in semi-elastic osteosynthesis of distal femoral fractures. *Stille-Werner*, Stockholm, Sweden 1981.
8. Kolmert, L., and Persson, B.M.: Supracondylar femoral fractures as a complication to Ender nailing of trochanteric fractures. A new device for osteosynthesis. *Arch Orthop Traumat Surg* 97(1): 51-55, 1980.
9. Kolmert, L., Persson, B.M., and Romanus, B.: An experimental study of devices for internal fixation of distal femoral fractures. Accepted for publication in *Clin Orthop*.
10. Kolmert, L., and Wulff, K.: Epidemiology and treatment of distal femoral fractures in adults. *Acta Orthop Scand*. Accepted for publication 1982.
11. Laros, G.S.: Supracondylar fractures of the femur: Editorial comment and comparative results. *Clin Orthop* 138:9-12, 1979.
12. Mahorner, H.R., and Bradburn, M.: Fractures of the femur. Report of 308 cases. *Surg Gynec and Obst* 56: 1066-1079, 1933.
13. Modlin, J.: Double skeletal traction in battle fractures of the lower femur. *Bull U.S. Army Med Dept*, No 4: 119-120, 1945.
14. Mooney, V., Nickel, L.V., Harvey, J.P., and Snelson, R.: Cast-Brace treatment for fractures of the distal part of the femur. *J Bone and Joint Surg* 52-A: 1563-1578, 1970.
15. Müller, M.E., Allgöwer, M., and Willenegger, H.: Manual of internal fixation. New York, Springer Verlag, 1970 och 1979.
16. Neer, C.S., Grantham, S.A., and Shelton, M.L.: Supracondylar fractures of the adult femur. A study of 110 cases. *J Bone and Joint Surg* 49-A: 591, 1967.

17. De Palma: The management of fractures and dislocations. Saunders, 1974.
18. Rush, L.V.: Dynamic intramedullary fracture fixation of the femur. Clin Orthop No 60: 21-27, 1968.
19. Schatzker, J., Horne, G., and Waddel, J.: The Toronto experience with supracondylar fracture of the femur. Injury 6, 113-128, 1974.
20. Schatzker, J., and Lambert, D.C.: Supracondylar fractures of the femur. Clin Orthop 138, 77-83, 1979.
21. Seinsheimer, F.: Fractures of the distal femur. Clin Orthop 153: 169-179, 1980.
22. Shelton, M.L., Grantham, S.A., and Neer, C.S., and Singh, R.: A new fixation device for supracondylar and low femoral shaft fractures. J Trauma 14: 821-835, 1974.
23. Stewart, M.J., Sisk, T.D., and Wallace, S.L.: Fractures of the distal third of the femur: A comparison of methods and treatment. J Bone and Joint Surg 48-A: 784-807, 1966.
24. Trentz, O., Tscherne, H., and Oestern, H.-J.: Operationstechnik und Ergebnisse bei distalen Femur Frakturen. Unfall heilkunde 80: 441-448, 1977.
25. Watson-Jones: Fractures and joint injuries. Churchill-Livingstone, London, 1976.
26. Umansky, A.L.: Blade-plate internal fixation for fracture of the distal end of the femur. Bull Hosp Joint Dis 9: 18-21, 1948.
27. White, E.H., and Russin, L.A.: Supracondylar fractures of the femur treated by internal fixation with immediate knee motion. Am Surgeon 22: 801-820, 1956.

28. Vidal, J., Dimeglio, A., and Buscayret, C.: Nos indications dans le traitement chirurgicale des fractures supra-condyliennes du fémur. *J Chir (Paris)* 111: 561-572, 1976.
29. Zickel, R.E., Fietti, V.G., Lawsing, J.F., and Cochran, G.V.B.: A new intramedullary fixation device for the distal third of the femur. *Clin Orthop* No 125: 185-191, 1977.

Reprinted from Archives of Orthopaedic and Traumatic Surgery 97,
51-55 (1980). J F Bergmann Verlag, München.

SUPRACONDYLAR FEMORAL FRACTURES AS A COMPLICATION
TO ENDER NAILING OF TROCHANTERIC FRACTURES

A New Device for Osteosynthesis

by

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SUMMARY

Supracondylar femoral fracture is an uncommon complication to Ender nailing of a trochanteric fracture. Seven cases were traced to study the fracture pattern and the results of the therapy. The most common fracture type extends obliquely from the hole of the insertion medially in a proximo-lateral direction. Prolonged traction in bed in these cases should be avoided. Rigid internal fixation using angle blade plates is frequently insufficient in highly osteoporotic bone. As an alternative to both traction in bed and rigid fixation a new osteosynthetic device for semi-elastic fixation was used as demonstrated in two of these cases. It has a connection piece between one elastic intramedullary nail of the Ender type and two cancellous bone screws. The device, applied from the medial as well as the lateral condyle, ensures a fixation less prone to mechanical failure in osteoporotic skeleton. It does not interfere with the loading forces of the bone and is stable enough to allow patients to be mobilized from bed. We now use it for all types of distal femoral fractures.

INTRODUCTION

Modern treatment of fractures has focused on attaining rapid mobility through stable fixation. The older the patient the more important is early mobility after fractures. Today we have several methods of internal fixation for patients with proximal femoral fractures allowing rapid weight-bearing. Nail and plate have been used for more than 20 years. Dimon and Hughston⁶ have described biomechanical failures after this procedure. Simon-Weidner¹⁴ and Ender⁷ using intramedullary elastic nail fixation from the supracondylar region emphasized the advantages of closed reduction and avoidance of exposing the fracture. Their technique also seemed to give less bleeding and shorter time in the operating room. Due to compression in the fracture, there is always some extrusion of the Ender nails at the knee. More pronounced extrusion might result in bad fixation of the fracture and impaired function of the knee. Supracondylar

fractures at the place of insertion are uncommon, but have attracted much attention because of the problems in treatment. This paper reports on a new device designed to solve the problem of distal femoral fractures like those caused by the insertion of Ender nails in trochanteric fractures. A number of similar cases were traced for review of fracture patterns and different methods of treatment.

MATERIAL

Seven relevant cases were found in an area of about 1 million inhabitants over a 3 to 4-year period in which an estimated 1.000 patients were operated on by the Ender method. The supracondylar fractures are schematically illustrated (Fig 1) and the operated cases (cases 5 and 7) are shown from X-rays.

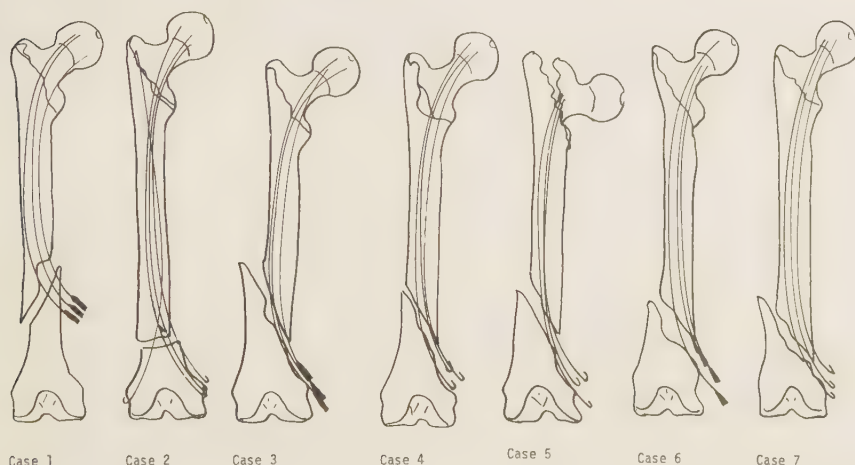


Fig 1. Seven supracondylar fractures of femur complicating Ender nailing for trochanteric fractures. To compare the fracture pattern cases involving left side are shown as right-sided. Insertion site has been too proximal especially in case 1. Nos 2 and 6 were per-operatively made. Nos 5 and 7 had been treated with the described osteosynthetic device and are shown in Figs 2-7.

Case 1. Female Patient, Aged 87, with Osteoporosis

After Ender nailing she had a fairly large defect at the place of insertion, which was higher than recommended by most authors. She sustained a supracondylar fracture and was treated in traction and healed in a rather bad position with the proximal fragment in front of the distal and several centimetres of shortening.

Case 2. Female Patient, Aged 84, with Osteoporosis

The predrilling in the medial condyle was done with a chisel and hammer and the patient subsequently fractured as shown. It was immediately recognized by the surgeon, who chose a lower place in the condyle and inserted three nails from the medial side and one from the lateral. She had an external fixation by a plaster slab and cast-brace 4 weeks postoperatively and healed in both fractures.

Case 3. Female Patient, Aged 72

Three weeks after Ender nailing of a trochanteric fracture she tripped over her crutches and sustained a supracondylar femoral fracture when doing walking exercises at home. She was treated with traction for many weeks.

Case 4. Male Patient, Aged 83

Because of a supracondylar fracture at the place of insertion he was treated with extraction of the Ender nails from the medial side. Another nailing of the same type was performed from the lateral side and supplemented by two cerclages over the fracture. Because of malposition even these nails had to be taken out and the patient was given a cast-brace. The fracture united after many months with some shortening.

Case 5. Female Osteoporotic Patient, Aged 96

She sustained a supracondylar femoral fracture one week after Ender nailing of a trochanteric fracture. Closed reduction and plaster fixation were performed because of her advanced age (Fig 2). However, it was not possible to keep both fractures in an acceptable position. After extraction of the intramedullary nails, the hip fracture was stabilized by nail and plate. To be able to mobilize the patient, avoiding bed rest, her distal femoral fracture was treated by shortened Ender nails, inserted one from each condyle, 1.5 cm over the tibio-femoral articulation. A small metal piece was fitted on each nail. It was supplemented by two cancellous screws from both condyles (Figs 3 and 4). The patient was given a plaster slab on the anterior side of her leg. In the postoperative phase, she was able to sit in a chair, instead of having to endure traction in bed.

Case 6. Female 66-year-old Diabetic

She had undergone operation of a pertrochanteric fracture of her left femur. Towards the end of the operation a supracondylar fracture was identified. Tibial traction was provided and the patient had to stay in bed for 3 weeks. A hexalite plaster was then applied for another 3 months.



Fig 2.



Fig 3.

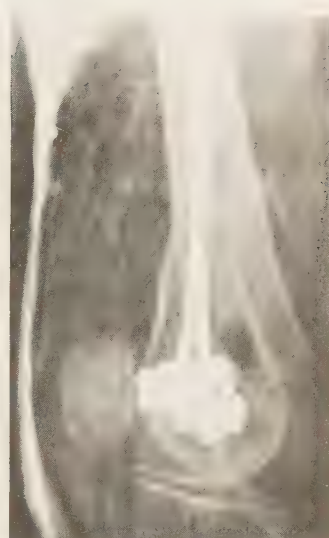


Fig 4.

Figs 2-4. Fig 2. Case 5. Female, aged 96. Supracondylar fracture at the insertion site. The Ender nails have extruded at the knee and at the trochanteric fracture. Fig 3. Semi-elastic osteosynthesis for distal femoral fracture. Antero-posterior view. Fig 4. Same as Fig 3. Side-view.

Case 7. Female Osteoporotic Patient, Aged 92

After a fall on a staircase she sustained a trochanteric fracture. Following initial tibial traction, she was operated on 2 days later according to the Ender method. A week later she fell from her bed and had a supracondylar fracture at the insertion site (Fig 5). Two long Ender nails were kept for the trochanteric fracture and from each condyle shortened Ender nails were introduced. The metal piece and cancellous screws gave a good osteosynthesis and the patient was mobilized at first with a plaster slab and then with a cast-brace. Figures 6 and 7 show the healed fractures.

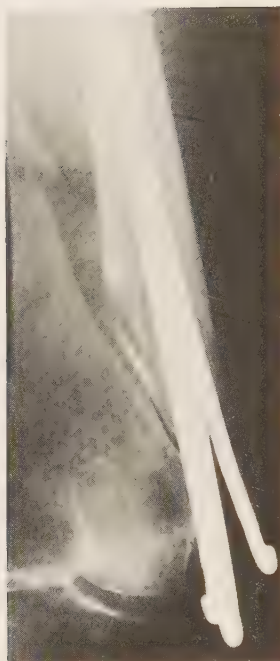


Fig 5.



Fig 6.

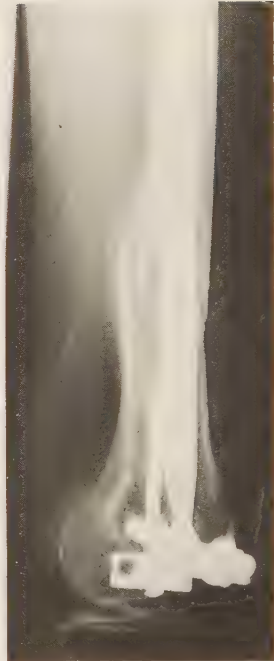


Fig 7.

Figs 5-7. Case 7. Female, aged 92. Ender-nailed for trochanteric fracture. Supracondylar fracture at the insertion place one week later (Fig 5). One Ender-nail was extracted, two were left inside the distal part and supplemented by the new device with one shortened Ender-nail from each side with the metal piece and one cancellous screw. Antero-posterior view in Fig 6, lateral view in Fig 7.

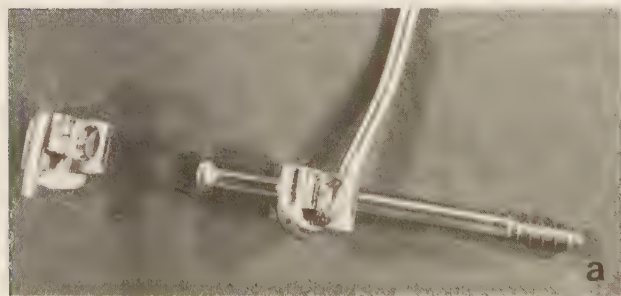


Fig 8. The new device before use. The single metal plate to the left and to the right connecting one Ender-nail and one cancellous screw. The little tongue has been bent down to lock the nail. The connecting device is designed for two cancellous screws, only one being shown.

METHOD

The technique reported on here combines rigid fixation of the condylar part by means of cancellous screws and a more elastic fixation to the diaphyseal tube with intramedullary nails of the Ender type. Because of limited space in the proximal femur (for instance formerly applied nail and plate or total hip prosthesis) the nails might be shortened. Apart from keeping the condyles well together, the small metal piece and cancellous screws prevent the Ender nails from extrusion or intrusion into the condyles. The method was designed for bi- and supracondylar fractures especially in osteoporotic bone and is called semi-elastic osteosynthesis (Fig 8).

RESULTS

The collected series of cases of supracondylar fractures following Ender nailing shows that the fracture occurs at the insertion site. In five cases the fracture line extends from the lower medial to the upper lateral aspect of the bone (Fig 1). Hence, the fracture pattern is roughly identical with the axis of predrilling and nailing. Case 1 has a large defect at the insertion site. In cases 2 and 6, the fractures occurred during operation, while in the five remaining cases, they were the results of falling accidents. Our study indicates that in this specific fracture the most common therapy was traction for 3-8 weeks followed by plaster slab or cast-brace. Internal fixation with additional Ender nails were used intraoperatively once (case 2) and once after several weeks in traction (case 4). This method, however, had the same disadvantages at this level as the Rush pin method, when the nails cut through the condyles.¹² Semi-elastic fixation avoided that and immediate post-operative mobilization was possible in both cases operated with this method.

DISCUSSION

Progress in orthopedic surgery in the last decades has produced increasing evidence of the advantages of early mobilization after surgery. An extremity immobilized because of fracture is exposed to loss of muscular power and skeletal minerals. The mineral content of a fractured bone will never reach the pretraumatic level.¹ Immobilized joints close to the fracture tend to be reduced of mobility sometimes on a permanent basis. The so-called "plaster disease" is generally caused by immobilization.

In 1979, Schatzker and Lambert,¹³ using internal fixation with AO-method reported failures in 9 of 19 operations on patients over 50 years of age with a distal femoral fracture. This figure could be compared to failures in just one of 17 when the patients were under 50.

At the Orthopedic Clinics in Malmö and Lund previous experiences of distal femoral fractures have shown that angle plates of the AO-type frequently turn out to be insufficient in osteoporotic skeleton.¹⁰ The use of Rush pins for the same fractures did not ensure a proper fixation and was mostly insufficient in stabilizing the distal fragments. Often extrusion or intrusion of the nails occurred in spite of additive external support by traction or plaster.¹⁰ Zickel's blade-shaped supracondylar nails were used in two cases.⁹ However, it did not fit the shape of the femoral shaft very well and it caused intercondylar dislocation in one case.

At the Department of Orthopedic Surgery in Lund a system of internal fixation of distal femoral fractures in osteoporotic patients is being developed. The method is based on a philosophy of semi-elastic fixation as apposed to rigid fixation by compression with screws and plates and have been used in more than 20 distal femoral fractures. The combination of an elastic nail connected to cancellous screws by a small metal piece (patented) was used in two cases of supracondylar fractures as complication to Ender nailing for trochanteric fracture.

By using the special Küntscher nail on trochanteric fractures, supracondylar fractures at the place of insertion were reported in a few per cent.⁵ Passl et al¹¹ using the Ender method indicate three cases of fracture at the insertion place out of 100 trochanteric fractures. Böhler and Kuderna⁴ have reported four cases in 2,137 patients operated by the same method. They stress the importance of making the insertion immediately above the condyles in the proximal part of the triangle behind the medial vastus muscle and in front of the adductor magnus tendon. Ender⁷ gave the same recommendations in 1974 and reported no supracondylar fractures. Hult and Nilsson⁸ had three such fractures in 990 Ender nailings. Two of these happened in the immediate postoperatively weight-bearing period and one when the nails were extracted.

CONCLUSIONS

To avoid distal femoral fractures in Ender nailing it should be noted that the insertion site should not be too proximal as in some of these instances. For appropriate preparation of the site we think it is important to use awl instead of chisel and hammer. If the hole needs to be enlarged this could be done by a bone rongeur. The nail is bent and carefully adjusted to the intramedullary canal as seen on the image intensifier. When the nails are introduced they should be directed proximally as to avoid perforation of the lateral cortex. They could often be introduced by hand with little or no hammering when passing the distal half of femur. If a supracondylar fracture is sustained after common Ender nailing the semi-elastic fixation avoids immobilization in bed by stabilizing the fracture.

REFERENCES

1. Andersson, S.: Activity, inactivity, and fracture. Thesis. University of Lund. Litos Reprotryck, Malmö AB, Sweden, 1978.
2. Benum, P., Reigstad, A., Vestby, G.W.: Operative fiksasjon av pertrochantære femurbrudd. Tidsskrift for den Norske Lægeforening 25:1320-1325, 1976.
3. Birkner, H., Persch, F.: Fehlerquellen bei der Versorgung pertrochanterer Frakturen nach Ender und Simon-Weidner. Unfallheilk 80:317-321, 1977.
4. Böhler, N., Kuderna, H.: Ergebnisse der Endernagelung in Österreich unter spezieller Berücksichtigung der Fälle des Lorenz-Böhler-Krankenhauses. Arch Orthop 88:339-346, 1977.
5. Collado, F., Vila, J., Beltran, J.E.: Condyle-cephalic nail fixation for trochanteric fractures of the femur. J Bone Jt Surg 55-B:774-779, 1973.
6. Dimon, J.H., Hughston, J.C.: Unstable intertrochanteric fracture of the hip. J Bone Jt Surg 49-A:440-450, 1967.
7. Ender, H.G.: Fixierung trochanterer Frakturen mit elastischen Kondylennägeln. Chir Praxis 18:81-89, 1974.
8. Hult, L., Nilsson, M.H.: Enderspikning av trochantära femurfrakturer. Läkartidningen 75:4603-4608, 1978.
9. Kolmert, L., Persson, B.: Två sorters Zickelspik för femurfraktur, proximalt respektive distalt. Svenska Läkaresällskapet, Riksstämman, November 1978.
10. Kolmert, L., Wulff, Ch.: Frakturer i distala femur - ett 8-års material från Malmö-Lund. Nordic Orthopaedic Association, Odense, June 1978.
11. Passl, R., Martinek, H., Paar, O., Spängler, H.: Ergebnisse der Fixierung pertrochanterer Frakturen mit Kondylennägeln nach Ender und Simon-Weidner. Chirurg 46:568-571, 1975.

12. Rush, L.V.: Dynamic intramedullary fracture fixation of the femur. Clin Orthop 60:21-27, 1968.
13. Schatzker, J., Lambert, B.C.: Supracondylar fractures of the femur. Clin Orthop Rel Res 138:77-83, 1979.
14. Simon-Weidner, R.: Die Fixierung trochanterer Brüche mit multiplen elastischen Rundnägeln nach Simon-Weidner. Unfallheilk 106:60-62, 1970.



